Skeletal Maturation in the Dog

A roentgenographic and skeletal study of the appearance of the ossification centres and union of the epiphyses in the bones of the limbs and bodies of the vertebrae.

A thesis for the Degree of Doctor of Veterinary Medicine and Surgery

by

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Summary

This study was undertaken with two objectives in mind: one objective was to obtain more definite information than had previously been available about the postnatal ages at which the ossification centres appear; the other was to establish when epiphyseal union takes place, since the findings of earlier investiagtors did not correspond and were inconclusive for one reason or another. Lesbre (1897) had carried out the first comprehensive study of the ossification process in the dog. His work had been accepted by veterinary anatomists in general, although his findings for those epiphyses that unite after the age of seven months had not been substantiated by the findings of later investigators. Lesbre's findings were approximate and, therefore, inconclusive because they had been based on dogs whose ages had been estimated by the teeth, while those of the later investigations were inconclusive either because of the material or because of the methods of study used.

The appearance of the ossification centres was studied by X-raying dogs from four breeds at regular intervals from birth. Epiphyseal union was studied by X-raying dogs from two breeds at regular intervals, and by examining the bones in seventy skeletons, seventy-one pectoral limbs, and one pelvis from dogs of known age. These dogs came from a variety of breeds, a number of which were achondroplastic. In addition, one hundred and twenty-six skulls from dogs of known ages were examined to study the dental changes that take place between the age of three and nineteen months, since it appeared to be important to assess the value of the teeth as a guide to the estimation of age in the dog.

Age periods have been established for the appearance of each of the centres that ossify after birth, and for the union of the epiphyses with their respective diaphyses. For both the appearance of the centres and the union of the epiphyses, it has been noted that the chronological order of events remains constant, but that there are age variations between individuals from the same litter or breed, and to a greater extent between individuals from different breeds. Neither sex nor the single dominant character for achondroplasia appears to influence the rate of skeletal maturation.

The study of epiphyseal union has provided definite evidence that after the age of seven months epiphyseal union takes place, on an average, five to seven months earlier than stated by Lesbre.

The dental study has indicated that the criteria by which Lesbre probably estimated the age of the dogs that he studied were innaccurate, because the amount of wear that he expected to find on the incisor teeth at a particular age is frequently seen about six months earlier.

The conclusion is that the probable explanation for the error in Lesbre's findings is that he had misestimated the age of the dogs that he studied.

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Introduction

Prior to 1884, little was known about the ossification process in the dog, and veterinary anatomical text-books, such as those by Zundel (1871) and Müller (1871), merely stated the number of ossification centres from which a bone developed, without mention of when these centres appeared or united with each other.

In 1884, Retterer published his findings on the development of the skeleton of the manus and pes in a number of domestic animals, including the dog. His findings were based on dissections, and it is doubtful whether he dissected many dogs because he was only able to establish that the time of appearance was in either the first or the second month (table 1). According to Fleming (1891), in his translation of Chauveau and Arloing's "Traité d'Anatomie Comparée des Animaux Domestiques", the course of ossification in the dog had also been studied by Touissant, who had established that the great majority of the epiphyses started to ossify during the first three months of life, that after this period only the ulnar carpal bone and the complementary nuclei of the os coxae remained in the cartilaginous state, and that the latter started to ossify at from five to six months. Fleming also stated that union of the epiphyses had been studied in the dog, but he did not mention by whom. As a result, it had been determined that epiphyseal union commenced at five months in the phalanges and metacarpal bones; that the corresponding epiphyses of the humerus and radius united at nine months; and that the nuclei of the proximal border of the scapula, the proximal extremity of the humerus, the distal extremity of the radius and ulna,

the epiphyses of the femur, and the bodies of the vertebrae could be distinguished at eighteen months.

In 1897, Lesbre published his monograph on the ossification of the skeleton of a number of the domestic animals, including the horse, ass, mule, ox, sheep, goat, pig (wild and domesticated), dog, cat, and rabbit. The results presented were based on a study of the material in the veterinary school at Lyons and in the museums at Lyons and Geneva, on the dissection of foetuses, and on the information contained in previous publications, namely those of Touissant and Retterer. It is clear from the figures given that Lesbre had examined a number of dogs of different ages (table 1), but there is no way of telling how many dogs of each age he examined and from what breeds they were taken. Nevertheless his work was a very worthwhile contribution, and although he pointed out at the time that it was not intended to be the last word, it developed into a fundamental work and has been accepted over the years: Lesbre's tables have been reproduced by Chauveau, Arloing, and Lesbre (1903) and again by Zietschmann and Krölling as recently as 1955; Montané, Bourdelle, and Bressou (1953) make reference to Lesbre's monograph and give ages for epiphyseal union that are almost identical with those given in the monograph; and Sisson (1914), and Sisson and Grossman (1938, 1953) also give figures for epiphyseal union that are very similar to those of Lesbre.

No further original work appears to have been carried out until Schaeffer (1934) studied the ossification process in the limbs by first staining the bones with alizarin red and then clearing them.

Twenty-six dogs were studied, nineteen of these having been killed at various ages from birth to five hundred and eighty-one days. The group was composed of a variety of breeds and, with a few exceptions, there was only one dog for each age.

Seoudi (1948) studied epiphyseal union in the limbs by X-raying Egyptian Armant dogs of known ages at selected intervals. Schlotthauer and Janes (1952) studied epiphyseal union at the distal end of the femur and proximal end of the tibia by X-raying a total number of eight dogs from several different breeds.

Pomriaskinsky-Kobozieff and Kobozieff (1954), and Bressou, Pomriaskinsky-Kobozieff and Kobozieff (1957) studied the ossification process in the manus and pes respectively using X-rays. This work was carried out on total number of ten dogs from three different breeds: one cocker spaniel was X-rayed at four to six day intervals from birth to one hundred and forty-two days; two German shepherds were X-rayed at four day intervals from one to forty-two days, and thereafter, at more widely spaced intervals to the age of eight months; a further five German shepherds were X-rayed at selected intervals; and finally two Breton spaniel x Irish setter crosses were X-rayed at ages of particular interest from six to forty-two days.

It is clear from this brief review that the ossification process in the dog has received considerable attention, but there are still aspects of it that require further investigation. The information available on the age of the appearance of the ossification centres for bones of the limbs and vertebral column is based on the findings of Retterer, Touissant, Lesbre, and Schaeffer, except in the manus and pes

for which there are also the findings of Pomriaskinsky-Kobozieff and Kobozieff, and Bressou, Pomriaskinsky-Kobozieff and Kobozieff. Touissant and Retterer have provided very general figures. Lesbre has provided more accurate information, but, like Touissant and Retterer, he relied on dissection and maceration, and probably had available only a limited number of dogs. Moreover dissection is not the best method of determining the time at which ossification centres appear, since in the beginning the centres are extremely small and hard to find. The method of first staining the bone with alizarin red and then clearing, as used by Schaeffer, is undoubtedly the most accurate, but it requires a large number of dogs to carry out a comprehensive study: Schaeffer's findings are therefore of limited value, because he had a small number of dogs available for study. Roentgenography provides great advantages in this type of investigation because the ossification process can be followed through the entire growth period of each animal.

The ages at which epiphyseal union occurs are also in doubt. Lesbre's findings have been generally accepted, but, as can be seen from table 1, the results of the investigations by Schaeffer, Seoudi, and Schlotthauer and Janes indicate that epiphyseal union may occur in certain bones, namely the radius, ulna, femur, tibia, and fibular tarsal, at an earlier age than stated by Lesbre. Furthermore, observations made on control dogs used in experimental work by Sellheim (1899), and Sutro and Pomerantz (1942) also indicate that epiphyseal union can occur earlier than stated by Lesbre. Schaeffer's results , however, are open to challenge, since, for the period in question, he

had only four dogs aged two hundred and eleven, two hundred and fifty-five, four hundred and seven, and five hundred and eighty-one days; and Seoudi's results were based on the study of an unstated number of dogs which belonged to a breed that is not known in Europe or North America* and which could conceivable have matured at an earlier age. There is also the possible argument that Schaeffer, Seoudi, and Schlotthauer and Janes obtained their results using methods other than dissection and maceration, which provide undeniable proof of epiphyseal union. Yet another point, which seems to have been overlooked, is that Lesbre stated in his monograph that his times for epiphyseal union in the dog were approximate, since the ages had been estimated by the teeth. Fortunately, it is possible to be fairly certain of the criteria that Lesbre applied for estimating the age of the dogs used in his study of the ossification process, because it is known that, prior to Lesbre's paper, Cornevin and Lesbre (1894) had published their criteria for ageing animals, including the dog, by the teeth, and it is likely that Lesbre used the same criteria.

The purpose of this investigation is, therefore, to determine by roentgenography the ages at which the ossification centres appear in the limbs and in the bodies of the vertebrae, and to determine by roentgenography and skeletal examination the ages at which epiphyseal union occurs. Another purpose is to determine by the examination of skulls of known ages whether or not the teeth are an accurate guide in the estimation of age, and therby to assess the value of the criteria established by Cornevin and Lesbre for ageing a dog by its teeth.

* The Egyptian Armant dog is not listed or described in Chambers

Encyclopaedia 1955, Encyclopaedia Brittanica 1958, or the Encyclopedia Americana 1957.

Table 1. To show the ages given by earlier workers and by veterinary anatomists for the appearance (A) of the ossification centres and union (U) of the epiphyses.

PECTORAL LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P.-K&K., &B, P.-K&K& G.Shep. BRSpXIrSe		Sisson & Grossman (1953)	Montané, Bourdelle, & Bressou
Scapula									
Scapulartuberosity	A.	—	2m	42d	—	—	—	—	—
" "	U.	—	6-8m	150d	6m	—	—	6-8m	6-8m
Humerus									
Head (prox.epi.)	A.	—	10-15d	1 1/2d	B-1m	—	—	—	—
" " "	U.	—	13m or 18m	407d	12m	—	—	1y	18m
Greater tubercle	A.	—	2m	—	B-1m	—	—	—	—
" "	U.	—	—	—	12m	—	—	—	—
Trochlea (med.part)	A.	—	20-25d	12-13d	—	—	—	—	—
Trochlea (lat.part) and capitulum.	A.	—	15-20d	12-13d	—	—	—	—	—
Troch.(m) with troch. (l) and Capit.	U.	—	—	117d	—	—	—	—	—
Med. epicondyle	A.	—	2m	49d	—	—	—	—	—
Med.epicondyle&troch.	U.	—	—	150d	—	—	—	—	—
Distal epiphysis	U.	—	6-8m	—	7-8m	—	—	6-8m	6-8m
Radius									
Prox.epiphysis	A.	—	1m	23d	1m	—	—	—	—
" "	U.	—	6-8m	255-407d	9m	—	—	6-8m	6-8m

PECTORAL LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P-K&K., &B, G.Shep.	P-K&K* BrSpXIr.Se	Sisson & Grossman (1953)	Montané, Bourdelle,& Bressou
Radius (cont.)									
Distal epiphysis	A.	___	1m	23d	___	12d	17d	___	___
" "	U.	___	16-18m	255-407d	12m	___	___	18m	16-18m
Ulna									
Olecranon	A.	___	1-2m	49d	2m	___	___	___	___
"	U.	___	15m	150d*	10m	___	___	15m	15m
Distal epiphysis	A.	___	1-2m	42d	2m	28-30d	34-36d	___	___
" "	U.	___	15m	211-255d	12m	___	___	15m	15m
Carpus									
Radial	A.	1-2m	34-35d	23-28d	___	24-26d	34-36d	___	___
Intermediate	A.	1-2m	34-35d	23-28d	___	13d	22-26d	___	___
Central	A.	1-2m	___	23-28d	___	24-26d	24-26d	___	___
Rad., inter., and cent.	U.	___	___	112d	___	R&C 60d 3m	___	___	___
Ulnar	A.	1-2m	___	29d	___	27-28d	42d	___	___
Accessory	A.	B-1m	10-15d	12d	___	10d	10-12d	___	___
Epi. of accessory	A.	1-2m	___	49d	___	40d	___	___	___
" " "	U.	___	___	117d	___	4-4 1/2m	___	___	___
Carpal I	A.	1-2m	34-35d	13-23d	___	16d	20-26d	___	___

PECTORAL LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P-K&K.,&B, P-K&K* G.Shep. Br.SpXInSe		Sisson & Grossman (1953)	Montane Bourdelle,& Bressou
Carpus (cont.)									
Carpal II.	A.	1-2m	34-35d	23-28d	___	20d	34-36d	___	___
Carpal III.	A.	1-2m	34-35d	23-28d	___	19d	34-36d	___	___
Carpal IV.	A.	1-2m	34-35d	13-23d	___	15-16d	22-26d	___	___
Metacarpus									
Epi. mtc. I.	A.	___	___	42d	___	31-34d	34-36d	___	___
" " "	U.	___	___	211d	8mm	6 1/2m	___	___	___
Epi. mtc. II.	A.	1-2m	34-35d	23d	___	19d	26d	___	___
" " "	U.	___	5-6m	211d	8m	7m	___	5-6m	5-6m
Epi. mtc. III.	A.	1-2m	34-35d	23d	___	19d	26d	___	___
" " "	U.	___	5-6m	211d	8m	7m	___	5-6m	5-6m
Epi. mtc. IV.	A.	1-2m	34-35d	23d	___	19d	26d	___	___
" " "	U.	___	5-6m	211d	8m	7m	___	5-6m	5-6m
Epi. mtc. V.	A.	1-2m	34-35d	23d	___	19d	26d	___	___
" " "	U.	___	5-6m	211d	8m	7m	___	5-6m	5-6m
Digits									
Epi. prox. ph. I.	A.	___	___	___	___	20-21d	34-36d	___	___
" " " "	U.	___	___	___	6m	6 1/2m	___	5-6m	___

PECTORAL LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P-K&K.,&B,B-K&K* G.Shep. BrSpXIrSe		Sisson & Grossman (1953)	Montane Bourdelle,& Bressou
Digits (cont.)									
Epi. prox. ph. II.	A.	1-2m	1-2m	23d	___	20-21d	26d	___	___
" " " "	U.	___	6m	255d	7m	6 1/2m	___	5-6m	___
Epi. prox. ph. III.	A.	1-2m	1-2m	23-28d	___	20-21d	26d	___	___
" " " "	U.	___	6m	255d	7m	6 1/2m	___	5-6m	___
Epi. prox. ph. IV.	A.	1-2m	1-2m	23-28d	___	20-21d	26d	___	___
" " " "	U.	___	6m	255d	7m	6 1/2m	___	5-6m	___
Epi. prox. ph. V.	A.	1-2m	1-2m	23-28d	___	20-21d	26d	___	___
" " " "	U.	___	6m	255d	7m	6 1/2m	___	5-6m	___
Epi. mid. ph. II.	A.	1-2m	1-2m	28-42d	___	20-21d	26d	___	___
" " " "	U.	___	6m	255d	6m	6 1/2m	___	5-6m	___
Epi. mid. ph. III.	A.	1-2m	1-2m	28-42d	___	20-21d	26d	___	___
" " " "	U.	___	6m	255d	6m	6 1/2m	___	5-6m	___
Epi. mid. ph. IV.	A.	1-2m	1-2m	28-42d	___	20-21d	26d	___	___
" " " "	U.	___	6m	255d	6m	6 1/2m	___	5-6m	___
Epi. mid. ph. V.	A.	1-2m	1-2m	28-42d	___	20-21d	26d	___	___
" " " "	U.	___	___	255d	6m	6 1/2m	___	5-6m	___

PECTORAL LIMB		Retterer	Lesbre	Schaeffer	Seoudi	B-K&K.,&B,BK&K* G.Shep. BrSpXInSe		Sisson & Grossman (1953)	Montane Bourdelle,& Bressou
Sesamoids									
Phacoid	A.	—	—	—	—	4m	—	—	—
Volar sesamoids	A.	—	2-3m	49d	—	60d	—	—	—
Dorsal sesamoids	A.	—	—	121d	—	—	—	—	—
PELVIC LIMB									
Os Coxae									
Os acetabulum	A.	—	—	49d	—	—	—	—	—
Acetabulum, ilium, ischium, pubis	U.	—	6m	150d	6m	—	—	6m	6m
Ischium, pubis	U.	—	—	150d	—	—	—	—	—
Crest of ilium	A.	—	4-6m	117d	—	—	—	—	—
" " "	U.	—	1 1/2-2y	starts 581d	2y	—	—	2y	1 1/2-2y
Sciatic tuber	A.	—	4-6m	117d	—	—	—	—	—
" "	U.	—	1 1/2-2y	407d	—	—	—	2y	1 1/2-2y
Ischial arch	A.	—	—	255d	—	—	—	—	—
" "	U.	—	—	407d	—	—	—	—	—
Interischial bone	A.	—	—	—	—	—	—	—	—

PELVIC LIMB		Retterer	Lesbre	Schaeffer	Seoudi	R-K&K., &B, R-K&K* G.Shep. BrSpXInSe		Sisson & Grossman (1953)	Montané Bourdelle,& Bressou
Os Coxae (cont.)									
Interischial bone	U.	—	—	—	—	—	—	—	—
Ossa coxarum	U.	—	—	—	24m+	—	—	—	—
Femur Head	A.	—	3-4w	1 1/2-10d	—	—	—	—	after birth
"	U.	—	—	407d	—	—	—	1 1/2y	1 1/2y
Trochanter major	A.	—	4-5w	49d	—	—	—	—	after birth
Trochant.maj.& head	U.	—	—	—	—	—	—	—	—
Prox. epiphysis	U.	—	1 1/2y	407d	10m	—	—	1 1/2y	1 1/2y
Trochanter minor	A.	—	—	49d	—	—	—	—	after birth
" "	U.	—	—	255d	—	—	—	—	1 1/2y
Dist. epiphysis	A.	—	3w	12d	—	—	—	—	—
" "	U.	—	1 1/2y	407d	12m	—	—	1 1/2y	1 1/2y
Tibia Condyles	A.	—	3-4w	12d	—	—	—	—	—
Tibial tuberosity	A.	—	2m	49d	—	—	—	—	2-3m
Cond.and tib. tub.	U.	—	—	—	—	—	—	—	—
Prox. epiphysis	U.	—	18m	255-407d	12-13m	—	—	18m	14-16m 18m(tub.)

PELVIC LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P-K&K.,&B, P-K&K* G.Shep. BnSp.XInSe		Sisson & Grossman (1953)	Montane Bourdelle,& Bressou
Tibia (cont.)									
Dist. epiphysis	A.	___	3-4w	13d	___	11d	___	___	___
" "	U.	___	14-15m	255-407d	11m	15-18m	___	14-15m	14-16m
Medial malleolus	A.	___	___	42d	___	70d	___	___	___
" "	U.	___	___	___	___	127d	___	___	___
Fibula									
Prox. epiphysis	A.	___	2 1/2m	49d	___	___	___	___	2-2 1/2m
" "	U.	___	___	255-407d	12m	___	___	___	___
Dist. epiphysis	A.	___	2m	29d	___	24d	___	___	___
" "	U.	___	___	255-407d	___	15-18m	___	___	___
Fibular tarsal	A.	B-1m	at birth	at birth	___	at birth	___	___	___
Tarsus									
Epi.fibular tar.	A.	1-2m	1 1/2-2m	42d	___	35-36d	36d	___	___
" " "	U.	___	14-15m	255d	7m	154-220d	___	14-15m	___
Tibial tarsal	A.	B-1m	B-34,35d	at birth	___	at birth	___	___	___
Central	A.	1-2m	34-35d	13-23d	___	14-15d	___	___	___
Tarsal I.	A.	1-2m	34-35d	23-28d	___	26d	___	___	___
Tarsal II.	A.	1-2m	34-35d	23-28d	___	25d	___	___	___

PELVIC LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P-K&K.,&B.,P-K&K† G.Shep. BnSpXInSe		Sisson & Grossman (1953)	Montane Bourdelle,& Bressou
Tarsus (cont.)									
Tarsal III.	A.	1-2m	34-35d	23-28d	___	19-21d	___	___	___
Tarsal IV.	A.	1-2m	34-35d	12d	___	8-9d	13d	___	___
Metatarsus									
Mtt. I.	A.	___	___	49d	___	42-43d	___	___	___
Epi. mtt. I.	A.	1-2m	___	___	___	47d	___	___	___
" " "	U.	___	___	___	___	79d	___	___	___
Epi. mtt. II.-IV.	A.	1-2m	3-4w	28d	___	22-23d	___	___	___
" " " "	U.	___	5-6m	211d	8m	240d	___	5-6m	___
Epi. mtt. V.	A.	1-2m	3-4w	28d	___	26d	___	___	___
" " "	U.	___	5-6m	211d	8m	240d	___	5-6m	___
Digits									
Prox. ph. I.	A.	___	___	___	___	56d	___	___	___
Epi. prox. ph. II.	A.	1-2m	1-2m	28d	___	25d	___	___	___
" " " "	U.	___	6m	___	7m	160-184d	___	5-6m	___
Epi. prox. ph. III.	A.	1-2m	1-2m	28d	___	25d	___	___	___
" " " "	U.	___	6m	___	7m	160-184d	___	5-6m	___

PELVIC LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P-K&K., &B, P-K&K* G.Shep. Br.SpXIrSe		Sisson & Grossman (1953)	Montane Bourdelle,& Bressou
Digits (cont.)									
Epi. prox. ph. IV.	A.	1-2m	1-2m	28d	___	25d	___	___	___
" " " "	U.	___	6m	___	7m	160-184d	___	5-6m	___
Epi. prox. ph. V.	A.	1-2m	1-2m	28d	___	25d	___	___	___
" " " "	U.	___	6m	___	7m	160-184d	___	5-6m	___
Epi. mid. ph. II.	A.	1-2m	1-2m	28-42d	___	34d	___	___	___
" " " "	U.	___	6m	___	6m	160-184d	___	5-6m	___
Epi. mid. ph. III.	A.	1-2m	1-2m	28-42d	___	34d	___	___	___
" " " "	U.	___	6m	___	6m	160-184d	___	5-6m	___
Epi. mid. ph. IV.	A.	1-2m	1-2m	28-42d	___	34d	___	___	___
" " " "	U.	___	6m	___	6m	160-184d	___	5-6m	___
Epi. mid. ph. V.	A.	1-2m	1-2m	28-42d	___	34d	___	___	___
" " " "	U.	___	___	___	6m	160-184d	___	5-6m	___
Sesamoids									
Lateral fabella	A.	___	___	112d	___	___	___	___	___
Medial fabella	A.	___	___	150d	___	___	___	___	___
Popliteal	A.	___	___	150d	___	___	___	___	___

PELVIC LIMB		Retterer	Lesbre	Schaeffer	Seoudi	P.-K.&K., &R.	P.-K.&K.* G.Shep.	BrSpXIrSe	Sisson & Grossman (1953)	Montané Bourdelle,& Bressou
Sesamoids (cont.)										
Patella	A.	___	2m	49d	___	___	___		___	2-3m
Plantar sesamoids	A.	___	2-3m	49d	___		60-70d	___	___	___
Dorsal "	A.	___	___	121-150d	___	___	___		___	___

A - appear U - unite B - birth

d - day m - month Br.Sp.X Ir.Se. - Breton Spaniel x Irish Setter

w - week y - year

* Pomriaskinsky-Kobozieff and Kobozieff
Bressou, Pomriaskinsky-Kobozieff, and Kobozieff

Material and Methods

The roentgenographic study was carried out on dogs of four breeds, namely the German shepherd, collie, bulldog, and beagle. The German shepherds, bulldogs, and beagles were litter mates, but the collies that were examined came from two litters. All the dogs were X-rayed at intervals, starting soon after birth; at first the intervals were short, but as the dogs grew older, the intervals became longer. The number of dogs examined, their sex, and the ages at which they were X-rayed are given in table 2. From this table, it can be seen that twenty-four dogs, with nearly even sex distribution, were examined through the first three weeks of their lives, and fourteen dogs, with even sex distribution, were examined through the first eight weeks of their lives. Three German shepherds were examined up to the age of four hundred and fifty days, and four collies up to the age of two hundred and seventy-seven days.

Prior to being X-rayed, the dogs were anaesthetized with a barbiturate. *Surital Sodium (thiamylal solium) was found to be the anaesthetic of choice. At every examination, an attempt was made to survey the entire skeleton of each dog and to obtain two views of each part: distal to the elbow or stifle, the limbs were usually examined only on the left side. When the puppies were young, the entire skeleton could be viewed on one

* Surital Sodium - manufactured by Parke, Davis and Company.

film, but as the puppies increased in size, the area of the body that could be viewed on a single film was decreased, until eventually a number of films had to be taken of each dog. For the study of the limbs and vertebral column, the following views were obtained:- lateral and ventrodorsal of the head and cranial part of the neck; lateral and ventrodorsal of the shoulder, thorax, and caudal part of the neck; mediolateral and dorsovolar of the pectoral limb; lateral and ventrodorsal of the lumbar vertebrae, pelvis and femora; and mediolateral and plantardorsal of the pelvic limb. The positioning of the dog and the X-ray technique for the various views have been described elsewhere (Hare 1959, 1960).

The dogs were housed in kennels with outside runs. The kennels were converted portable poultry houses and the runs, which measured fourteen by ten feet, were placed on concrete. Two or three dogs were housed in each kennel.

The puppies were fed cereal and milk, and received cod liver oil daily. After weaning, the dogs were fed canned dog food, supplemented with minerals and vitamins whenever necessary. Regular worm egg counts were made, and treatment was given if required. The puppies received regular doses of anti-canine distemper serum up to the age of three months, at which time they were vaccinated against canine distemper and infections canine hepatitis. Rabies vaccine was also administered to all the dogs.

The skeletal and dental studies were carried out on part of the material that Stockard (1941) had collected during his study on genetics. Only material from dogs for which records of the exact age at death were available was used in these studies.

Seventy skeletons, seventy-one pectoral limbs, and one pelvis were used to study the limbs and vertebrae. A large part of this material was drawn from the collection which Stockard made during the breeding experiments that he carried out to study achondroplasia of the extremities. Eighteen breeds were used in these experiments. Three of the breeds, namely the bassethound, the dachshund, and the Pekingese, exhibited marked achondroplasia of the limbs. They were crossed with normal straight limbed animals to produce first and second generation hybrids, and the first generation hybrids were also backcrossed with both the parent stocks. Since, as Stockard concluded, distorted growth is inherited as a single factor, dominant character, this material afforded an opportunity to study the age of epiphyseal union in bones from normal straight limbed animals and from animals exhibiting varying degrees of achondroplasia.

The teeth were examined on two hundred and one skulls from dogs aged from three to eighteen months. This material was drawn from the collection which Stockard made during his study of achondroplasia of the head and extremities, and many of the skulls showed poor dental occlusion. Because it was important that only those skulls carrying good teeth and showing good dental occlusion should be considered, only one hundred and twenty-six of these skulls were finally used to determine when the permanent teeth erupted and to record the amount of wear that had taken place at each age.

The sex and breeding records of the dogs from the Stockard collection which were used in these studies are given in Appendix "A". The age distribution of the dogs is given in Appendix "B".

The care and management of the dogs used in the breeding experiments have been fully described by Stockard (1931).

Thirteen of the seventy skeletons studied were X-rayed so that the roentgenographic criteria used to determine epiphyseal union could be verified by comparing the roentgenographic appearance of the bone with the state of the bone itself (figs. 12, 34, 41).

The humeri from three dogs aged five months were examined specially to determine whether or not there was a separate centre of ossification for the greater tuberosity. The method used was that of Haviland (1959). The bones were immersed in a two per cent solution of potassium hydroxide until the tissues were cleared. Then a saturated solution of alizarin red S. in ninety-five per cent alcohol was added to the two per cent solution of potassium hydroxide until it turned a wine colour. The bones were left in this solution until they were stained, at which time they were decolourized by immersing them in a solution consisting of equal parts of a ten per cent solution of glycerin and a two per cent solution of potassium hydroxide. After decolourization, the bones were cleared by passing them through ascending grades of glycerin; 25%, 30%, 75% and 100%.

Table 2. To show the ages at which the dogs were examined, and the number and sex of the dogs examined.

G. Shepherd		Collie (1st litter)		Collie (2nd litter)		Bulldog		Beagle	
Days	No. & Sex	Days	No. & Sex	Days	No. & Sex	Days	No. & Sex	Days	No. & Sex
3	3M,4F	3	3M,4F	3	2M,2F	0	1M,1F	3	4M,2F
6	3M,4F	7	3M,4F	4	1M,1F	2	1M,1F	7	4M,2F
10	3M,4F	11	3M,3F	5	1M,1F	4	1M,1F	11	4M,2F
15	3M,4F	17	3M,3F	6	1M,1F	8	1M	14	4M,2F
22	3M,4F	21	3M,3F	7	1M,1F	9	1M	21	4M,2F
30	3M,4F	26	3M,3F	8	1M,1F	10	2M	28	2M,2F
46	2M,3F	34	2M,3F	9	1M,1F	11	2M	42	2M,2F
65	2M,2F	40	2M,3F	10	1F	15	2M	60	2M,2F
95	2M,2F	55	2M,3F	11	1M,1F	17	2M	66	2M,2F
109	1F	69	2M,3F	12	1F	19	2M	69	2M,2F
130	1M,2F	83	2M,3F	13	1M,1F	25	1M	75	1M,1F
162	1M,2F	97	2M,3F	14	1F	31	1M	82	2M,2F
203	1M,2F	111	2M,3F	17	1M,2F	38	1M		
226	1M,2F	118	2M,3F	19	1M,2F	45	1M		
259	1M,2F	132	2M,3F	21	1M,2F	52	1M		
287	1M,2F	158	2M,3F	23	1M,2F	59	1M		
320	1M,2F	186	2M,3F	25	1M,2F	68	1M		
357	1M,2F	214	2M,3F	28	1M,2F	80	1M		
378	1M,2F	249	2M,2F	31	1M,2F	94	1M		
402	1M,2F	277	2M,2F			108	1M		
450	1M,2F					121	1M		
						135	1M		
						156	1M		

The second litter of collies was divided into two groups, which were examined on alternate days from the fourth to the seventeenth day. From the seventeenth day on, both groups were examined together. The litter of bulldogs was divided into two groups at birth and examined on alternate days to the ninth day, thereafter the surviving dogs from each group were examined together.

Criteria

The criterion for the appearance of an ossification centre was taken to be the first appearance of an opaque area on the roentgenogram.

Roentgenographically, just prior to epiphyseal union being considered complete, an epiphyseal line of increased density could be seen between the diaphysis and the epiphysis. In addition, on the surface of the bone a break could be seen where the diaphysis met the epiphysis (fig. 13). Complete epiphyseal union was considered to have taken place when the epiphyseal line appeared less dense, when bony trabeculae could be seen passing from the diaphysis to the epiphysis along the entire length of the line, and when the surface of the bone appeared smooth (figs. 7, 8). The epiphyseal line may persist for some time after epiphyseal union is complete (figs. 11,12).

In the macerated bones, five stages of epiphyseal union were recognized after the method adopted by McKern and Stewart (1957): stage "0" union indicated that no union had taken place; stage "1" union indicated that epiphyseal union had recently started, and that bony trabeculae were passing from the diaphysis to the epiphysis in the centre of the union; stage "2" union indicated that the union was more advanced than in stage "1" union and that an increased number of bony trabeculae were passing from the diaphysis to the epiphysis (fig. 20a); stage "3" union indicated that union was nearly complete, but that there was still a break in the surface of the bone between the diaphysis and epiphysis (figs. 9b, 16d, 37b, 40a); and stage "4" union indicated that epiphyseal union was complete.

FINDINGS

Scapula

The scapula develops from two centres of ossification; one for the body and spine, which is present at birth; and one for the scapular tuberosity, which appears after birth.

Table 3. To show the age of the roentgenographic appearance (A) and union (U) of the centre of ossification for the scapular tuberosity. (number of dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Scapular tuberosity	A.	30-46d (5)	40-55d (5)	52d (1)	42-60d (4)
	U.	130-162d (3)	132-158d (5)	___	___

Table 4. To show the age distribution for the stages of union for the scapular tuberosity based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
4m	(381) (427)		(275)		
5m			(88) (345) (1890)		
6m				(215)	(133)
7m					(125)
7 1/2m					(404)

The results of the roentgenographic investigation (table 3) indicate that the centre of ossification for the scapular tuberosity appears during the fifth, sixth, seventh, or eighth week depending on the breed (fig. 1). The roentgenographic investigation combined with the skeletal study (tables 3, 4) indicates that the centre

for the scapular tuberosity unites with the body of the bone during the fifth, sixth, or seventh month (figs. 2, 19a).

Humerus

The humerus develops from five centres of ossification; one for the body (diaphysis), which is present and well developed at birth; one for the head and tubercles (proximal epiphysis); and one each for the capitulum and lateral part of the trochlea, the medial part of the trochlea, and the medial epicondyle. The line of union between the lateral and medial parts of the trochlea lies sagittally in the groove of the trochlea (fig. 19b).

Table 5. To show the age of the roentgenographic appearance (A) and union (U) of the centres of ossification for the humerus. (number and sex of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Prox. epiphysis	A.	3-6d (7)	3-5d,4-6d (1M) (2) 5-7d,3-7d (1F) (7)	8d,9d (1)(1)	7-11d (6)
" "	U.	320-357d (3)	———	———	———
Capitulum and trochlea	A.	6-10d (7)	10d,11d,13d (1F)(2M) (1F) 11-17d (6)	15d,17d (1) (1)	14d,14-21d (1M) (5)
" " "	U.	———	———	———	———
Med. epicondyle	A.	30-46d (5)	40-55d (5)	52-59d (1)	42-60d (4)
" "	U.	130-162d (3)	132-158d (5)	———	———
Dist. epiphysis	U.	226-259d (3)	186-214d (5)	———	———

The results of the roentgenographic investigation (table 5) indicate that the centre of ossification for the proximal epiphysis appears during the first or second week of life (figs. 3,4), that the centres for the combined capitulum and lateral part of the trochlea and for the medial part of the trochlea appear during the second or third week of life (figs. 3,4), and that the centre for the medial epicondyle does not appear until the fifth, sixth, seventh, or eighth week (fig. 5).

Table 6 To show the age distribution for the stages of union for the proximal epiphysis of the humerus with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
10m	(811)(1359) (1518)(1520) (1700)		(695)	(1699)	
10 1/2m	(1519)	(652)		(1746)	
11m					
11 1/2m	(653)(1686)			(977)(1698)	
12m	(1632)(1635) (1636)			(1633)	
12 1/2m			(1695)	(1683)(1696)	
13m	(1924)			(1747)	
13 1/2m					(76)
14m				(1522)(1523) (1526)	(93)(916) (917)(918) (919)
14 1/2m				(1525)	(518)

All humeri from dogs aged fifteen months or more showed the proximal epiphysis completely united with the diaphysis.

Table 7 To show the age distribution for the stages of union for the distal epiphysis of the humerus with diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
6m	(133)(215)				
6 1/2m					
7m					(125)
7 1/2m					(404)
8m					(123)(160) (210)(657)

With regard to the union of the centres of ossification, it was not possible to determine roentgenographically the age at which union occurs between the medial and lateral parts of the trochlea, but an examination of skeletons 174 and 481 indicated that it occurs during the fourth month (fig.20f). The results of the roentgenographic investigation (table 5) and skeletal study (tables 6,7) indicate that union of the proximal epiphysis with the diaphysis can occur during the twelfth, thirteenth, fourteenth, or fiftheenth month (figs. 9b, 10, 16b, c, d). The centre for the medial epicondyle unites with the trochlea during the fifth or sixth month (fig. 19d), and the distal epiphysis thus formed unites with the diaphysis during the seventh or eighth month (figs. 9c, 13, 15a, b).

Radius

The radius develops from three centres of ossification: one for the body (diaphysis), which is present and well developed at birth; and one each for the head (proximal epiphysis) and the distal epiphysis.

Table 8 To show the age of the roentgenographic appearance (A) and union (U) of the centres of ossification for the radius. (number and sex of the dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Prox. epiphysis	A.	15-22d (4) 22-30d (3)	21d,23d,25d (1M) (2) (1F) 21-26d (5)	31-38d (1)	21-28d (4)
" "	U.	287-320d (3)	277d (4)	———	———
Dist. epiphysis	A.	10-15d (5) 15-22d (2)	11-17d,13-17d (2) (2) 17-19d,17-21d (1) (4)	25d (2)	14-21d,21-28d (1) (3)
	U.	320-357d (3)	———	———	———

The results of the roentgenographic investigation (table 8) indicate that the centre of ossification for the proximal epiphysis appears during the third, fourth, or fifth week (fig. 6), and that the centre for the distal epiphysis appears a little earlier during the second, third, or fourth week (fig. 6).

The results of the roentgenographic investigation (table 8) and the skeletal study (tables 9, 10) indicate that the proximal epiphysis unites with the diaphysis during the ninth or tenth month (figs. 7, 11a, 15a, b), and that the union of the distal epiphysis with the diaphysis generally occurs later during the ninth, tenth, eleventh, or twelfth month (figs. 8, 10, 11a, 15a, b).

Table 9. To show the age distribution for the stages of union for the proximal epiphysis of the radius with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
7m			(125)		
7 1/2m	(404)				
8m	(123)(160) (214)(657)				
8 1/2m					
9m					(1847)
9 1/2m					
10m					(695)(811)(1359) (1518)(1520) (1699)(1700)

Table 10. To show the age distribution for the stages of union for the distal epiphysis of the radius with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
8m	(123)(214)			(657)	(160)
8 1/2m					
9m					(1847)
9 1/2m					
10m				(1518)(1520) (1700)	(811)(695) (1359)(1699)
10 1/2m				(1519)	(652) (1746)
11m					
11 1/2m					(653)(977) (1686) (1698)

Ulna

The ulna develops from three major centres of ossification: one for the body (diaphysis), which is present and well developed at birth; one for the olecranon; and one for the distal epiphysis. In two dogs (table 11), the olecranon developed from two small centres, which united rapidly, and in one dog (table 11), the distal epiphysis developed from two small centres, which likewise united rapidly.

Table 11. To show the age of the roentgenographic appearance (A) and union (U) of the olecranon and distal epiphysis of the ulna. (number of dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Olecranon	A.	30-46d (5) 2 dogs,2 centres	40-55d (5)	52-59d (1)	42-60d (4)
"	U.	226-259d (3)	214-249d (4)	—	—
Dist. epiphysis	A.	30-46d (5) 1 dog 2 centres	40-55d (5)	59d (1)	42-60d (4)
" "	U.	259-287d (3)	277d (4)	—	—

The results of the roentgenographic investigation (table 11) indicate that the centres of ossification for the olecranon and the distal epiphysis appear during the second month of life (fig. 17). As a general rule, the centre for the distal epiphysis was much better developed than that for the olecranon at the end of the age period, but the bulldog was an exception since at fifty-nine days the centre for the olecranon was easily visible, whereas that for the distal epiphysis was just appearing.

Table 12. To show the age distribution for the stages of union for the olecranon of the ulna with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
6m	(133)		(215)		
6 1/2m					
7m					(125)
7 1/2m					(404)
8m					(123)(160) (214)(657)

Table 13. To show the age distribution for the stages of union for the distal epiphysis of the ulna with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
8m	(123)(214)			(160)(657)	
8 1/2m					
9m					(1847)
9 1/2m					
10m				(811)(1518) (1520)(1700)	(695)(1359) (1699)
10 1/2m				(1519)	(652)(1746)

All ulnae from dogs aged eleven month or more showed the distal epiphysis completely united with the diaphysis.

The results of the roentgenographic investigation (table 11) and the skeletal study (tables 12,13) indicate that the olecranon unites with the diaphysis during the seventh or eighth month (figs. 9a,13), and that the distal epiphysis unites with the diaphysis during the ninth, tenth, or eleventh month (figs. 11b,12,14,15a,b).

Carpus

The carpus develops from ten centres of ossification. There is one centre each for the ulnar, first, second, third, and fourth carpal bones. The accessory carpal bone develops from two centres, one for the body and one for the epiphysis. The radial carpal bone represents the fusion of the radial, intermediate, and central carpal bones and develops from three centres, one for each of these bones.

The findings listed in table 14 show that the age at which the various centres of ossification appear in the carpus differs from one breed to another, and to a much lesser degree between individual animals within a breed. There may also be a slight variation in the chronological order of appearance. However, it can be said in general terms that the centre of ossification for the body of the accessory carpal bone is the first to appear usually during the second week (fig.48c), and that the other centres of ossification appear during the third to ninth weeks (fig.6), with the centre for the epiphysis of the accessory carpal bone the last to appear (figs.17,44).

According to the roentgenographic (table 14) and skeletal examinations, the centres of ossification for the radial, intermediate, and central carpal bones unite during the fourth month (figs.19e,20c). The epiphysis of the accessory carpal bone unites with the body during the fourth or fifth month (tables 14, 15)(figs. 18,20b).

Table 14. To show the age of the roentgenographic appearance (A) of the centres of ossification for the carpal bones, the union (U) of the centres of the radial, intermediate, and central carpal bones, and the union (U) of the epiphysis of the accessory carpal bone with the body. (number and sex of the dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Radial	A.	15-22d (2) 22-30d (5)	25d,25-28d (1M) (2F) 26d,26-34d (2) (3)	38-45d (1)	28-42d (4)
Intermediate	A.	10-15d (7)	17-19d,19-21d (2) (1F) 17-21d,21-26d (2) (4)	31-38d (1)	21d (1) 21-28d
Central	A.	22-30d,30d (5) (2)	31d,26-34d (2) (5)	59-68d (1)	42-60d (4)
Radial intermed. & central	U.	95-130d (3)	97-111d (5)	121-135d (1)	———
Ulnar	A.	22-30d (7)	21-26d,26-34d (2) (3) 25d,25-28d (1M) (2)	59-68d (1)	28-42d (4)
Accessory	A.	6-10d (7)	8d,9d (2) (2) 7-11d (6)	17d (2)	11-14d,14-21d,21-28d (2) (2) (2)
Epiphysis acc.	A.	30-46d,46-65d (4) (1)	40-55d (5)	59-68d (1)	42-60d (4)
" "	U.	95-130d (3)	111-118d (2) 118-132d (3)		
Carpal I	A.	15-22d (7)	19d,21d (3) (3) 21-26d (3)	31-38d (1)	21-28d (3) 28-42d (1)
Carpal II	A.	22-30d (3) 30-46d (2)	23d,25d (1F)(1M) 25-28d,21-26d (1F) (6)	52-59d (1)	28-42d (4)
Carpal III	A.	22-30d (7)	23d,25d,21-26d (1F)(2) (6)	38-45d (1)	28-42d (4)

Table 14 (cont.)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Carpal IV	A.	15-22d (7)	19d (3) 17-21d, 21-26d (4) (2)	28-31d (1)	21-28d (3) 28-42d (1)

Table 15. To show the age distribution for the stages of union for the epiphysis of the accessory carpal bone with the body based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
3 1/2m	(174)(481)				
4m	(427)			(381)	
4 1/2m					(275)
5m				(1890)	(88)(345)

All accessory carpal bones from dogs over the age of five months showed the epiphysis completely united with the body.

Os Coxae

The os coxae develops from seven or eight centres of ossification. There is one centre each for the ilium, ischium, pubis, and os acetabulum, the crest of the ilium, and the sciatic tuber. The ischial arch develops from one or more centres. In addition, there is a centre of ossification for a small, wedge-shaped piece of bone located in the angle of divergence between the ischia at the caudal end of the symphsis pelvis; in the ox, this piece of bone was called the interischial bone by early veterinary anatomists.

The ilium, ischium, and pubis are ossified at birth, but the centres are separated by considerable areas of cartilage in the

region of the acetabulum and along the symphysis pelvis. As growth proceeds, the three bones approximate each other in the region of the acetabulum, and the symphyseal rami of the ischium and pubis grow closer together.

Table 16. To show the age of the roentgenographic appearance (A) and union (U) of the centres of ossification for the os coxae. (number of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Os acetabulum	A.	46-65d (4)	55-69d (5)	68-80d (1)	———
Ilium, ischium, pubis & os acetabulum	U.	130-162d (3)	158-186d (5)	———	———
Pubis and ischium	U.	130-162d (3)	158-186d (5)	———	———
Crest of ilium	A.	95-130d (3)	111-118d (5)	121-135d (1)	———
" " "	U.	starts 357-378d (3)	———	———	———
Sciatic tuber	A.	46-65d (4)	55-69d (2) 69-83d (3)	80-94d (1)	———
" "	U.	259-287d (1) 287-320d (2)	———	———	———
Ischial arch	A.	160-203d (3)	158d (5)	———	———
" "	U.	402-450d (2)	———	———	———
Interischial bone	A.	130-162d (3)	118-132d (5)	———	———
" "	U.	———	———	———	———

The results of the roentgenographic investigation (table 16) indicate that the centre of ossification for the os acetabulum appears during the eighth, ninth, tenth, or eleventh week (fig. 21). This centre is difficult to distinguish roentgenographically, and it was not possible to determine when it appeared in the beagle. The centre of ossification for the sciatic tuber appears toward the end of the second or during third month (fig.22). The centre of ossification for the crest of the ilium appears during the fourth or early in the fifth month (fig. 23). The centre of ossification for the interischial bone appears during the fifth month (figs.23,24), and the one or more centres for the ischial arch during the sixth month (fig. 26).

Table 17. To show the age distribution for the stages of union between the ilium, ischium, pubis, and os acetabulum, based on skeletal examination. (skeleton number in parenthesis)

	Stages of Union				
Age	0	1	2	3	4
3 1/2m	(174)(481)				
4m			(381)(427) Ischium, pubis, & os acetabulum united		
4 1/2m					(275)
5m			(88) Ischium, pubis & os acetabulum united	(345)	
5 1/2m					
6m					(133)(215)

Table 18. To show the age distribution for the stages of union between the ischium and pubis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
3 1/2m	(481)				
4m				(427)	(381)
4 1/2m					(275)
5m					(88)(345)

The results of the roentgenographic investigation (table 16) and skeletal study (tables 17,18) show that the ilium, ischium, pubis, and os acetabulum unite during the fifth or sixth month, with the ischium, pubis, and os acetabulum uniting with each other before they unite with the ilium (figs. 25,27a). The symphyseal rami of the ischium and pubis also unite during the fifth or sixth month but generally a little earlier than the ilium, ischium, pubis, and os acetabulum unite in the region of the acetabulum (fig. 25).

From tables 16, 19, and 20, it can be seen that, on the basis of the roentgenographic and skeletal examinations, the sciatic tuber unites with the ischium during the tenth, eleventh, or twelfth month, and that the ischial arch unites with the ischium during the twelfth, thirteenth, or fourteenth month (figs.27b,c,31).

The age at which the crest of the ilium unites with the ilium is quite variable, and usually the process of union extends over a lengthy period. Union can start to take place at about one year of age, and in one dog (skeleton number 402), it was complete at the age of fifteen months. Skeletons examined from dogs aged from two to five and one-half years showed stage "3" union of the crest in about one half of the cases and stage "4" union in the other half.

Table 19. To show the age distribution for the stages of union for the sciatic tuber with the ischium based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
8m	(123)(160) (214)(657)				
8 1/2m					
9m					
9 1/2m					
10m	(695) (811 rt. side)			(811 lt. side)	(1359)
10 1/2m					(652)
11m					
11 1/2m				(653)	(977)

All ossa coxarum examined from dogs aged one year or more had the sciatic tuber completely united with the ischium.

Table 20. To show the age distribution for the stages of union for the ischial arch with the ischium based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
9 1/2m					
10m	(695) (811 rt. side)	(811 lt. side)	(1359)		
10 1/2m				(652)	
11m					
11 1/2m		(653)			(977)
12m					
12 1/2m					
13m					
13 1/2m					(76)
14m					(93)(916)(917) (918)(919)

The union of the interischial bone with the ischia is associated with the union of the ossa coxarum along the symphysis pelvis. The process starts at the caudal end of the symphysis pelvis, when the interischial bone begins to unite with the left and right ischia, and then progresses cranially. On the basis of skeletal examinations, complete union of the interischial bone with the ischia takes place in some dogs around fifteen months, but in others not until twenty-one months. The age at which complete union occurs between the ossa coxarum is very variable, as can be seen from table 21.

Table 21. To show the age distribution of the stages of union between the ossa coxarum based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
14m	(518)(916) (917)(918) (919)		(93)		
15m	(667)(668) (669)(1146) (1251)		(402)(403)		
16m					
17m	(666)	(782)			
18m	(876)				
19m	(106)(352) (779)				
20m	(524)(525)				
21m	(532)				
22m					
23m					
24-30m		(294)			(1072)
30-36m			(84)(209)	(210)(231)	
36-42m	(295)	(296)		(114)(739)	(486)(1083)
42-48m	(130)		(134)	(109)	
48-54m					(833)
54-60m		(128)		(85)(252)	(156)
60-66m					(122)
66-72m			(127)	(234)	(120)(230)
72-78m					
78-84m			(277)		
84-90m					

Femur

The femur develops from five centres of ossification: one for the body (diaphysis), which is present and well developed at birth; and one each for the head, the trochanter major, the trochanter minor, and the medial and lateral condyles (distal epiphysis).

Table 22. To show the age of the roentgenographic appearance (A) and union (U) of the centres of ossification for the femur. (number and sex of dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Head	A.	3-6d, 6-10d (2) (5)	3-7d, 7-11d (2) (4) 5d, 6-8d (1M) (2) 7-9d (1F)	11-15d (2)	11-14d (2) 14-21d (4)
Trochanter major	A.	30-46d (5)	34-40d (2) 40-55d (3)	52-59d (1)	60d (4)
Trochanter major & head	U.	259-287d (3)	249-277d (4)	———	———
Prox.epiphysis	U.	287-320d (3)	———	———	———
Trochanter minor	A.	46-65d (4)	40-55d (5)	68-80d (1)	66-69d (4)
" "	U.	287-320d (3)	———	———	———
Dist.epiphysis	A.	10-15d (7)	7-11d, 11-17d (2) (4) 11d, 11-13d (1M) (1F) 12d (1F)	19-25d (1)	14-21d (3) 21-28d (1M)
" "	U.	287-320d (3)	249-277d (2)	———	———

The results of the roentgenographic investigation (table 22) indicate that, depending on the breed, the centre of ossification for the head of the femur appears during the first, second, or third week of life (fig.28). The centre for the trochanter major appears during the second month (fig.29), and the one for the trochanter minor during the seventh, eighth, ninth, tenth, or eleventh week, (fig.29). The centre for the distal epiphysis appears during the second, third, or fourth week (fig.28).

Table 23. To show the age distribution of the stages of union between the trochanter major and the head of the femur based on skeletal examination. (skeleton number in parenthesis)

	Stages of Union				
Age	0	1	2	3	4
6m	(133)(215)				
6 1/2m					
7m					(125)
7 1/2m				(404)	
8m		(160)			(123)(214)(657)

Table 24. To show the age distribution of the stages of union between the head of the femur and the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
9 1/2m					
10m				(695)(811)	(1359)
10 1/2m			(652)		
11m					
11 1/2m				(653)	(977)
12m					
12 1/2m					
13m					
13 1/2m					(76)

Table 25. To show the age distribution for the stages of union for the trochanter major of the femur with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
9m					
9 1/2m					
10m			(811)	(695)	(1359)
10 1/2m				(652)	
11m					
11 1/2m				(653)	(977)
12m					
12 1/2m					
13m					
13 1/2m					(76)

The roentgenographic (table 22) and skeletal (tables 23,24,25,26) examinations indicate that the centres of ossification for the head and trochanter major unite with each other over the proximal end of

the neck of the femur prior to their union with the diaphysis (figs.20d,30). This union usually takes place during the eighth or ninth month, although it may occur earlier. The proximal epiphysis, formed by the union of the head with trochanter major, unites with the diaphysis during the tenth, eleventh, or twelfth month (figs.31,33a,b,c), while the trochanter minor unites with the diaphysis at about the same time. The distal epiphysis unites with the diaphysis during the ninth, tenth, eleventh, or twelfth month (figs.32,33,51a,b).

Table 26. To show the age distribution for the stages of union for the distal epiphysis of the femur with the diaphysis based on skeletal examinations. (skeleton number in parenthesis)

	Stages of Union				
Age	0	1	2	3	4
9m					
9 1/2m					
10m	(695)(811)				(1359)
10 1/2m				(652)	
11m					
11 1/2m	(653)				(977)

All femora examined from dogs aged one year or more showed the distal epiphysis completely united with the diaphysis.

Tibia

The tibia develops from five centres of ossification: one for the body (diaphysis), which is present and well developed at birth; one for the medial and lateral condyles; one for the tibial tuberosity; one for the main part of the distal epiphysis; and one for the medial malleclus.

Table 27. To show the age of the roentgenographic appearance (A) and union (U) for the centres of ossification for the tibia. (number and sex of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Condyles	A.	10-15d (7)	11-17d,13d (6) (1M) 13-17d (1F) 17-19d (1)	19-25d (1)	14-21d (1M) 21-28d (3)
Tib. tuberosity	A.	46,46-65d (4) (1F)	40-55d (5)	68-80d (1)	42-60d (4)
Condyles and tuberosity	U.	226-259d (3)	214-249d (4)	———	———
Prox. epiphysis	U.	320-257d (3)	277d (1)	———	———
Dist. epiphysis	A.	10-15d (7)	11-17d (6) 13-17d (1M) 17-19d (2)	25-31d (1)	21-28d (4)
Med. malleolus	A.	65-95d (3)	55-69d (5) (closer to 69d)	80-97d (1)	———
" "	U.	95-130d (3)	97d (5)	108-121d (1)	———
Dist. epiphysis	U.	259-287d (3)	249-277d (4)	———	———

The results of the roentgenographic investigation (table 27) indicate that the centres of ossification for the condyles and the distal epiphysis appear during the second, third, or fourth week (fig.35). The centre of ossification for the tibial tuberosity appears during the seventh, eighth, ninth, tenth, or eleventh week, depending on the breed (fig.38). The centre of ossification for the medial malleolus appears during the third month and unites with the distal epiphysis a few weeks later (figs.36a,19c).

Table 28. To show the age distribution for the stages of union of the tibial tuberosity with the condyles based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
6m		(215)	(133)		
6 1/2m					
7m					(125)
7 1/2m					(404)
8m		(214)		(657)	(123) (160)

Table 29. To show the age distribution for the stages of union for the proximal epiphysis of the tibia with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
9m					
9 1/2m					
10m	(811)	(695)		(1359)	
10 1/2m				(652)	
11m					
11 1/2m				(653)	(977)
12m					

The results of the roentgenographic investigation (table 27) and skeletal study (tables 28,29,and 30) show that the tibial tuberosity unites with the condyles during the seventh, eighth, or ninth month (fig.20e), and that the proximal epiphysis, thus formed, unites with the diaphysis during the tenth, eleventh, or twelfth month (figs.37a,51a). The union of the proximal epiphysis with the diaphysis is frequently incomplete, distal to the region where the tibial tuberosity and condyles unite, for some time after the main part of the condyles and the tuberosity have united with the diaphysis; hence the number of tibiae showing stage "3" union (figs.37b,c). The distal epiphysis unites with the diaphysis during the ninth or tenth month (fig.37b,c).

Table 30. To show the age distribution for the stages of union for the distal epiphysis of the tibia with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
8m	(123)(160) (657)		(214)		
8 1/2m					
9m					
9 1/2m					
10m					(811)(695) (1359)
10 1/2m					(652)
11m					
11 1/2m					(653)(977)

Fibula

The fibula develops from three centres of ossification: one for the body (diaphysis), which is present and well developed at birth; and one each for the proximal and distal epiphyses.

Table 31. To show the age of the roentgenographic appearance (A) and union (U) of the centres of ossification for the femur. (number of dogs in parenthesis)

Centre	Breed			
	G. Shepherd	Collie	Bulldog	Beagle
Prox. epiphysis A.	30-46d (closer to 46d) (5)	34-55d (3) 40-55d (2)	69-80d (1)	60-66d (4)
" " U.	320-357d (3)	277d (1)	———	———
Dist. epiphysis A.	22-30d (7)	28-31d (3) 26-34d (5) (2dogs-2 centres)	42-52d (1)	28-42d (3)
" " U.	357-378d (1) 378-402d (2)	———	———	———

The results of the roentgenographic investigation (table 31) indicate that the centre of ossification for the proximal epiphysis appears during the second or early in the third month (fig.38). The centre of ossification for the distal epiphysis appears during the fourth, fifth, sixth, or seventh week (fig.39). In two dogs, the distal epiphysis developed from two centres which fused rapidly.

Table 32. To show the age distribution for the stages of union for the proximal epiphysis of the fibula with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
8m	(123)(160) (214)	(657)			
8 1/2m					
9m					
9 1/2m					
10m	(811)			(695)	(1359)
10 1/2m				(652)	
11m					
11 1/2m					(977)(653)
12m					

Table 33. To show the age distribution for the stages of union for the distal epiphysis of the fibula with the diaphysis based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
8m	(123)		(657)		(160)(214)
8 1/2m					
9m					
9 1/2m					
10m					(695)(811) (1359)
10 1/2m					(652)
11m					
11 1/2m					(653)(977)

The results of the roentgenographic investigation (table 31) and the skeletal study (tables 32,33) show that the proximal epiphysis unites with the diaphysis during the tenth or eleventh month (figs. 34,40a,b,41,51a), and that the distal epiphysis unites with the diaphysis sometime between the eighth and the thirteenth month (fig.40a,b).

Tarsus

The tarsus of the dog is composed of seven bones. There is one centre of ossification for each bone with the exception of the fibular tarsal bone, which has two, one for the body and one for the epiphysis at the proximal end of the tuber calcis. The centres of ossification for the tibial tarsal bone and the body of the fibular tarsal bone are present at birth. The remaining centres appear after birth.

The results of the roentgenographic investigation (table 34) indicate that in the tarsus, as in the carpus, the ages at which the centres of ossification appear vary from one breed to another and, to a lesser degree, between individual animals within a breed. There is, however, little variation in the chronological order of appearance. In all the breeds under study, the centre of ossification for the fourth tarsal bone is the first to appear during the second or third week, and the centre of ossification for the central tarsal is the second to appear during the second, third, fourth, or fifth week (fig.28). The centre of ossification for the third tarsal appears next (figs.35,45), followed by the centres for the first and second tarsal bones (fig.39). The centre of ossification for the epiphysis of the fibular tarsal bone is the last to appear, and in two dogs, this centre developed from two small centres which fused rapidly (fig. 42). By the end of the second month, all the centres of ossification are present. The results of the roentgenographic (table 34) and skeletal (table 35) examinations

show that the epiphysis of the fibular tarsal bone unites with the body during the sixth or seventh month (fig.43).

Table 34. To show the age of the roentgenographic appearance (A) of the centres of ossification for the bones of the tarsus, and the union (U) of the epiphysis of the fibular tarsal bone with the body. (number and sex of the dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Fibular tarsal	A.	Ante natal	Ante natal	Ante natal	Ante natal
Epiphysis fib. tar.	A.	30-46d,46d (4) (1) (2 centres in 2 dogs)	34d,34-55d (1M) (2) 40-55d (2)	52-59d (1)	42-60d (4)
" " "	U.	162-203d (2) 203-226d (1)	186-214d (5)	———	———
Tibial tarsal	A.	Ante natal	Ante natal	Ante natal	Ante natal
Central tarsal	A.	10-15d (7)	11d,13d,14d (1M)(1F)(1F) 11-17d (6)	31-38d (1)	11-14d (2) 14-21d (3) 21-28d (1M)
Tarsal I	A.	30-46d (5)	25-28d (1M) 28-31d (2) 26-34d (5)	38-45d (1)	28-42d (4)
Tarsal II	A.	22-30d (6) 30-46d (1)	25d,25-28d (1F) (2) 26-34d (5)	45-52d (1)	28-42d (4)
Tarsal III	A.	15-22d (2) 22-30d (5)	21-23d (3) 21-26d (6)	31-38d (1)	21-28d (3) 28-42d (1M)
Tarsal IV	A.	7-10d,10-15d (5) (2)	9d,12d,13d (1M)(1F)(1F) 7-11d,11-17d (2) (4)	19d (1)	11d,11-14d (1) (4) 14-21d (1M)

Table 35. To show the age distribution for the stages of union for the epiphysis of the fibular tarsal bone with the body based on skeletal examination. (skeleton number in parenthesis)

Age	Stages of Union 0	1	2	3	4
5m	(88)		(345)		
5 1/2m					
6m			(215)		(133)
6 1/2m					
7m					(125)
7 1/2m					(404)

Metacarpus and Metatarsus

The functional digits of the dog are the second, third, fourth, and fifth; and the metacarpal and metatarsal bones that articulate with these digits are the best developed. Each develops from two centres of ossification: one for the body (diaphysis), which is present and well developed at birth; and one for the head (distal epiphysis). In the metacarpus and the metatarsus, the centres of ossification for the distal epiphyses of the third and fourth bones appear first, followed very soon by the centre for the second bone, and a little later by the centre for the fifth bone. Since the difference in time is very slight, the four bones have been grouped together in tables 36 and 37. It can be seen from these tables that the centres for the metatarsal bones appear slightly later than those for the metacarpal bones (figs. 44,45). The roentgenographic investigation and skeletal study show that the epiphyses of the metacarpal and metatarsal bones unite with the diaphyses during the sixth or seventh month.

Table 36. To show the age of the roentgenographic appearance (A) and union (U) of the distal epiphysis with the body in metacarpal bones II-V. (number and sex of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Epiphyses mtc. II-V	A.	22d, 22-30d (3) (4)	23-25d (3) 21-25d, 26-34d (3) (2)	31-38d (1)	28d (3) 28-42d (1M)
" " " "	U.	162-203d (3)	158-186d (1) 186-213d (4)	———	———

Table 37. To show the age of the roentgenographic appearance (A) and union (U) of the distal epiphysis with the body in metatarsal bones II-V. (number and sex of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Epiphyses mtt. II-V	A.	22-30d (7)	25-28d, 26-34d (3) (5)	45d (1)	28-42d (4)
" " " "	U.	203-226d (3)	186-214d (5)	———	———

The first metacarpal bone develops from two centres of ossification: one for the body (diaphysis), which is present at birth; and one for the proximal epiphysis.

Table 38. To show the age of the roentgenographic appearance (A) and union (U) of the proximal epiphysis of the first metacarpal bone with the body. (number of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Epiphysis mtc. I	A.	30-46d (5)	40-55d (5)	42-52d (1)	28-42d (4)
" " "	U.	162-203d (3)	158-186d (5)	———	———

The results of the roentgenographic investigation (table 38) indicate that the centre of ossification for the epiphysis of the first metacarpal bone appears later than those of the other metacarpal bones: it is first seen during the fifth, sixth, or seventh week, depending on the breed. The roentgenographic and skeletal investigation show that the epiphysis unites with the body during the sixth or seventh month, which is at the same time as epiphyseal union takes place in the other metacarpal bones.

The degree to which the first metatarsal bone is developed in the dog varies considerably. In all the dogs which were studied roentgenographically, it was very small and developed from a single centre of ossification, which appeared during the sixth, seventh, eighth, or ninth week, as shown in table 39 (fig. 42).

Table 39. To show the age of the roentgenographic appearance (A) of the first metatarsal bone. (number and sex of dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Metatarsal I.	A.	30-46d, 46-65d (1F) (3)	40-55d (5)	59d (1)	42-60d (4)

Digits

The functional digits II-V in both pectoral and pelvic limbs consist of three phalanges, proximal, middle, and distal. The proximal and middle phalanges are developed from two centres of ossification: one for the body, which is present at birth; and one for the proximal epiphysis. The distal phalanx is developed from one centre, which is present at birth. The epiphyses for the proximal phalanges appear earlier than those for the middle phalanges (fig.39), and the epiphyses in the pectoral limb usually appear a little earlier than those in the pelvic limb (tables 40,41,42 &43)(figs. 44,45). Also, as in the

metacarpus and metatarsus, the centres in the axial phalanges appear slighty earlier than those in the abaxial phalanges.

Table 40. To show the age of the roentgenographic appearance (A) and union (U) of the epiphyses for the proximal phalanges II-V in the pectoral limb. (number of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Epiphyses prox. ph. II-V	A.	22-30d (7)	21-26d (2) 26-34d,28d (3) (3)	31-38d (1)	28-42d (4)
" " " " " "	U.	162-203d (3)	158-186d (5)	———	———

Table 41. To show the age of the roentgenographic appearance (A) and union (U) of the epiphyses for the middle phalanges II-V in the pectoral limb. (number of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Epiphyses mid. ph. II-V.	A.	30d,30-46d (1) (4)	40-55d (5)	52-59d (1)	42-60d (4)
" " " " " "	U.	162-203d (3)	158-186d (5)	———	———

The centres of ossification for the epiphyses of the proximal phalanges II-V appear during the fourth, fifth, sixth, or seventh week, and those for the middle phalanges during the fifth, sixth, seventh, eighth, or ninth week.

Table 42. To show the age of the roentgenographic appearance (A) and union (U) of the epiphyses for the proximal phalanges II-V in the pelvic limb. (number of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Epiphyses prox. ph. II-V	A.	22-30d (7)	26-34d (5) 28-31d (3)	38-45d (1)	28-42d (4)
" " " "	U.	162-203d (3)	158-186d (5)	———	———

Table 43. To show the age of the roentgenographic appearance (A) and union (U) of the epiphyses for the middle phalanges II-V in the pelvic limb. (number of dogs in parenthesis)

Centre		Breed G. Shepherd	Collie	Bulldog	Beagle
Epiphyses mid. ph. II-V	A.	30-46d (5)	40-55d (5)	52-59d (1)	28-60d (4)
" " " "	U.	162-203d (3)	158-186d (5)	———	———

The results of the roentgenographic (tables 40,41,42,&43) and skeletal studies indicate that the epiphyses of the proximal and middle phalanges, in both the pectoral and pelvic limbs, unite during the sixth or early in the seventh month, usually a little earlier than the epiphyses of the metacarpal or metatarsal bones.

The first digit of the pectoral limb consists of two phalanges, a proximal and a distal. The proximal phalanx develops from two centres of ossification: one for the body, which is present at birth; and one for the proximal epiphysis. The distal phalanx develops from one centre, which is present at birth.

Table 44. To show the age of the roentgenographic appearance (A) and union (U) of the epiphysis of the proximal phalanx I in the pectoral limb. (number of dogs in parenthesis)

Centre		Breed			
		G. Shepherd	Collie	Bulldog	Beagle
Epiphysis prox. ph. I.	A.	30-46d (5)	40-55d (5)	52-59d (1)	42-60d (4)
" "	U.	162-203d (3)	158-186d (5)	———	———

The roentgenographic studies show that the centre of ossification for the epiphysis of the proximal phalanx I appears during the fifth, sixth, seventh, or eighth week, depending on the breed. This is at about the same time that those for the middle phalanges II-V appear, but later than those for the proximal phalanges II-V appear. Union of the epiphysis with the body of the bone occurs at the same time as in the other phalanges.

In none of the dogs that were used for the roentgenographic investigation were any of the phalanges developed in the first digit of the pelvic limb.

Sesamoid bones

The sesamoid bones found in the pectoral limb are the phacoid, a pair of volar sesamoids at the distal end of each metacarpal bone except the first where there is one, and a dorsal sesamoid on the dorsal aspect of each metacarpo-phalangeal articulation. Each sesamoid bone develops from a single centre of ossification.

Table 45. To show the age of the roentgenographic appearance of the centres of ossification for the sesamoids bones of the pectoral limb. (number of dogs in parenthesis)

Centre	Breed			
	G. Shepherd	Collie	Bulldog	Beagle
Phacoid	95d (4)	97d, 97-118d (3) (2)	121-138d (1)	—
Volar sesamoids	46-65d (4)	55-69d (5)	94-108d (1)	66d (2) 69-75d (2)
Dorsal sesamoids	109-130d (1) 95-130d (2)	118d (5)	121-138d (1)	—

The results of the roentgenographic investigation (table 45) show that the centres of ossification for the volar sesamoids are the first to appear and, depending on the breed, may do so between the seventh and fifteenth weeks. The centre of ossification for the phacoid is the next to appear during the fourth or first part of the fifth month, and it is followed closely by the centres for the dorsal sesamoid bones.

The sesamoid bones found in the pelvic limb are as follows: the medial and lateral fabellae situated in the tendons of origin of the medial and lateral heads of the m. gastrocnemius: the small sesamoid bone in the tendon of origin of the m. popliteus; the patella; a pair of planter sesamoid bones at the distal end of each metatarsal bone except the first unless a complete digit is developed; and a dorsal sesamoid bone on the dorsal aspect of each metacarpo-phalangeal joint. Each sesamoid bone develops from a single centre of ossification.

Table 46. To show the age of the roentgenographic appearance of the centres of ossification for the sesamoid bones in the pelvic limb. (number of dogs in parenthesis)

Centre	Breed			
	G. Shepherd	Collie	Bulldog	Beagle
Medial fabella	65-95d (4)	69-83d (5)	94-108d (1)	____
Lateral fabella	65-95d (4)	69-83d (5)	94-108d (1)	____
Popliteal sesamoid	65-95d,95d (2) (1)	83-97d (5)	135d (1)	____
Patella	30-46d (2) 46-65d (2)	40-55d (5)	68d (1)	60d,66d,69d (1M) (1F)(2)
Plantar sesamoids	46-65d (3)	40-55d (5)	94-108d (1)	66d (4)
Dorsal sesamoids	95-130d (3)	97-111d (5)	135-156d (1)	____

The results of the roentgenographic investigation show that the centre of ossification for the patella is the first to appear during the second or early in the third month. This is followed a little later, between the seventh and fifteenth weeks, by the centres of ossification for the plantar sesamoid bones. The latter appear at about the same time as the volar sesamoid bones, in some cases a little earlier, in others a little later. The centres of ossification for the medial and lateral fabellae appear during the third or early in the fourth month, while the centre of ossification for the sesamoid in the tendon of the m. popliteus appears later, during the fourth or first half of the fifth month (fig.38). The centres of ossification for the dorsal sesamoids appear during the fourth or fifth month.

Summary

The findings of the roentgenographic and skeletal studies for the pectoral and pelvic limbs are summarized in table 47.

Table 47. A summary of the findings of this investigation with regard to the appearance (A) of the ossification centres and the union (U) of the epiphyses for the pectoral and pelvis limbs.

Pectoral Limb			Pelvic Limb		
Centre or Epiphysis		**Period**	**Centre or Epiphysis**		**Period**
SCAPULA			OS COXAE		
Scapular tuberosity	A.	5th to 8th W.	Os acetabulum	A.	8th to 11th W.
" "	U.	5th to 7th M.	Ilium, ischium, pubis and os acetabulum	U.	5th or 6th M.
			Ischium and pubis	U.	5th or 6th M.
			Crest of ilium	A.	14th to 19th W.
			" " "	U.	15th M. to 5 1/2 Y.
			Sciatic tuber	A.	7th to 12th W.
			" "	U.	10th to 12th M.
			Ischial arch	A.	6th M.
			" "	U.	12th to 14th M.
			Interischial bone	A.	5th M.
			" "	U.	15th to 21st M.
			Ossa coxarum	U.	2nd to 6th Y.
HUMERUS			FEMUR		
Proximal epiphysis	A.	1st or 2nd W.	Head	A.	1st to 3rd W.
" "	U.	12th to 15th M.	Trochanter major	A.	5th to 8th W.

Pectoral Limb

Centre or Epiphysis		Period
HUMERUS (cont.)		
Trochlea (med. part)	A.	2nd or 3rd W.
Trochlea (lat. part) and capitulum	A.	2nd or 3rd W.
Troch. (m) and troch. (l) and capit.	U.	4th M.
Medial epicondyle	A.	5th to 8th W.
Medial epicondyle and trochlea	U.	5th or 6th M.
Distal epiphysis	U.	7th or 8th M.
RADIUS		
Proximal epiphysis	A.	3rd to 5th W.
" "	U.	9th or 10th M.
Distal epiphysis	A.	2nd to 4th W.
" "	U.	11th or 12th M.

Pelvic Limb

Centre or Epiphysis		Period
FEMUR (cont.)		
Head and troch. major	U.	8th to 9th M.
Proximal epiphysis	U.	10th to 12th M.
Trochanter minor	A.	7th to 11th W.
" "	U.	10th to 12th M.
Distal epiphysis	A.	2nd to 4th W.
" "	U.	9th to 12th M.
TIBIA		
Condyles	A.	2nd to 4th W.
Tibial tuberosity	A.	7th to 11th W.
Condyles and tib. tuber.	U.	7th to 9th M.
Proximal epiphysis	U.	10th to 12th M.
Distal epiphysis	A.	2nd to 4th W.
" "	U.	9th or 10th M.
Medial malleolus	A.	3rd M.
" "	U.	4th M.

Pectoral Limb

Centre or Epiphysis		Period
ULNA		
Olecranon	A.	5th to 8th W.
"	U.	7th or 8th M.
Distal epiphysis	A.	5th to 8th W.
" "	U.	9th to 11th M.
CARPUS		
Radial	A.	3rd to 6th W.
Intermediate	A.	2nd to 5th W.
Central	A.	3rd to 9th W.
Rad. int. and cent.	U.	4th M.
Ulnar	A.	3rd to 9th W.
Accessory	A.	2nd W.
Epiphysis of accessory	A.	7th to 9th W.
" " "	U.	4th or 5th M.
Carpal I.	A.	3rd to 5th W.
Carpal II.	A.	4th to 8th W.
Carpal III.	A.	4th to 6th W.
Carpal IV.	A.	3rd or 4th W.

Pelvic Limb

Centre or Epiphysis		Period
FIBULA		
Proximal epiphysis	A.	5th to 11th W.
" "	U.	10th or 11th M.
Distal epiphysis	A.	4th to 7th W.
" "	U.	8th to 13th M.
TARSUS		
Tibial tarsal	A.	antenatal
Fibular tarsal	A.	antenatal
Epiphysis of fib.tarsal	A.	5th to 8th W.
" " " "	U.	6th or 7th M.
Central	A.	2nd to 5th W.
Tarsal I.	A.	5th or 6th W.
Tarsal II.	A.	4th to 7th W.
Tarsal III.	A.	3rd to 6th W.
Tarsal IV.	A.	2nd or 3rd W.

Pectoral Limb

Centre or Epiphysis		Period
METACARPUS		
Epi. mtc. I.	A.	5th to 7th W.
" " "	U.	6th or 7th M.
Epi. mtc. II-V.	A.	4th to 7th M.
" " "	U.	6th or 7th M.
DIGITS		
Epi. prox. ph. I.	A.	5th to 8th W.
" " " "	U.	6th or 7th M.
Epi. prox. ph.II-V.	A.	4th to 7th W.
" " " " "	U.	6th or 7th M.
Epi. mid. ph. II-V.	A.	5th to 8th W.
" " " " "	U.	6th or 7th M.
SESAMOID BONES		
Phacoid	A.	4th or 5th M.
Volar sesamoids	A.	7th to 15thM.
Dorsal "	A.	4th or 5th M.

Pelvic Limb

Centre or Epiphysis		Period
METATARSUS		
Mtt. I.	A.	6th to 9th W.
Epi. Mtt. II-V.	A.	4th to 8th W.
" " " "	U.	6th or 7th M.
DIGITS		
Epi. prox. ph. II-V.	A.	4th to 7th W.
" " " " "	U.	6th or 7th M.
Epi. mid. ph. II-V.	A.	5th to 8th W.
" " " " "	U.	6th or 7th M.
SESAMOID BONES		
Lat. and med. fabellae	A.	10th to 15th W.
Popliteal	A.	13th to 19th W.
Patella	A.	5th to 10th W.
Plantar sesamoids	A.	7th to 15th W.
Dorsal "	A.	4th or 5th M.

W - Week
M - Month
Y - Year

Vertebral column

The body of each vertebra, with the exception of the atlas and the axis, develops from three centres of ossification: one for the main part of the body, which is present and well developed at birth; and one each for the cranial and caudal epiphyses. The atlas is an atypical vertebra and is not considered to have a body. The body of the axis develops from four centres of ossification: one for the main part of the body; one each for the cranial and caudal epiphyses; and one for the dens, which is present at birth. The latter is situated cranially, and the centre for the cranial epiphysis appears between it and the body. The dens is considered to represent the body of the atlas.

The results of the roentgenographic investigation indicate that in each region of the vertebral column the centre for the cranial epiphysis of a vertebra appears slightly earlier than that for the caudal epiphysis (fig.48a). Taking into account the breed and individual differences in the time of the appearance, it can be stated in general terms that the centres of ossification for the epiphyses of the vertebrae appear as follows: those of the cervical, thoracic, and lumbar vertebrae during the second, third, or fourth week; those of the sacral and first two or three coccygeal vertebrae during the third, fourth, or fifth week; those of the next few coccygeal vertebrae during the fourth, fifth, or sixth week; and those of the remaining coccygeal vertebrae during the second or the first half of the third month.

Epiphyseal union was studied roentgenographically and on the skeletons. The results of the study indicate that the body of a vertebra usually unites with the cranial epiphysis before it unites

with the caudal epiphysis (fig.46), an observation that has also been made for the horse by Ussow (1902). Union occurs first between the cranial epiphysis, dens, and body of the axis and between the epiphyses and bodies of most caudal coccygeal vertebrae. It then proceeds from either end of the column towards the mid-thoracic region where the final complete union takes place. The age at which epiphyseal union takes place varies considerably. In some dogs, union starts during the seventh month, but in others, it does not start until the ninth month. In some dogs, the epiphyseal union is completed during the eleventh or twelfth month, but in others it is not completed in the mid-thoracic region until the fourteenth month.

Teeth

The teeth were examined in the skulls of dogs aged from three to seven months to determine the age at which the permanent teeth erupt, and, in the skulls of dogs aged from seven to nineteen months, to determine the amount of wear that has teken place on the incisor teeth at various ages.

Some variation was found in the times of eruption, and the results given should be considered as general. In fifteen out of a total of nineteen skulls examined from dogs aged from three to four months, the first premolars were erupting or had recently erupted; in the remaining four skulls only the deciduous teeth were present. In eleven skulls examined from dogs aged from four to five months, the upper and lower first and second incisors and the upper and lower first premolars and molars had erupted. In eight skulls examined from dogs aged from five to six months, all the incisors, the upper and lower first premolars, the upper fourth premolar, and the upper and lower first and second molars had erupted, and the canines and remaining premolars were in the process of erupting. In three out of a total of five skulls examined from dogs aged from six to seven months, all the permanent teeth had erupted, but in the other two, the upper second and third premolars, the lower fourth premolar, and the third molar had not yet erupted.

The crowns of the incisor teeth in the dog are trituberculate (fig.47a). When the crown is subjected to wear, the tubercles or cusps become worn down until eventually, on a labial view, the occlusal edge appears straight (fig.47c,d,e).

In two out of a total of three skulls examined from dogs aged

from seven to eight months, some wear was detected on the cusps of the lower first incisors. In two out of three skulls examined from dogs aged from eight to nine months, the cusps were worn off the lower first incisors, but in a third skull, the cusps were not worn. Four skulls were examined from dogs aged from nine to ten months; in two, the cusps were worn off the lower first incisors, but in the other two, little or no wear on the cusps was detected. In six out of eleven skulls examined from dogs aged from ten to eleven months, the cusps were worn off the lower first incisors, and in three of these, there was also wear on the cusps of the lower second incisors. In three more of the eleven skulls, some wear could be detected on the cusps of the lower first incisors, but in the other two there appeared to be no wear on the cusps of the lower first incisors. In four out of seven skulls examined from dogs aged from eleven to twelve months, the cusps were worn off the lower first incisors; and in three of these skulls, there was also wear on the cusps of the lower second incisors (fig.47b). In the other three skulls in this age group, there was some wear on the cusps of the first lower incisors. In five out of nine skulls examined from dogs aged from twelve to thirteen months, the cusps were worn off the lower first incisors and showed signs of wear on the lower second incisors (fig.47c). In three other skulls, there was wear on the cusps of the lower first incisors (fig.47d), but in one skull there was no sign of wear on the lower first incisor. Eleven skulls were examined from dogs aged from thirteen to fourteen months. In seven of these, the cusps were worn off the lower first incisors, and in three, there was also wear on the cusps of the lower second incisors (fig.47e). In the other four skulls, there

was wear on the lower first incisors. Nine skulls were examined from dogs aged from fourteen to fifteen months. In six of these skulls, the cusps were worn off the lower first incisors, and in two out of the six, there was also wear on cusps of the lower second incisor and the upper first incisor. In two of the nine skulls, there was some wear on the cusps of the lower first incisor, but in the other skull, the cusps were still present on the lower first incisor. Nine skulls were examined from dogs aged from fifteen to sixteen months. In five skulls, the cusps were worn off the lower first incisors and worn on the lower second incisor, and in two of these skulls, there was also wear on the cusps of the upper first incisors. In two skulls, the cusps were worn off the lower first incisors, and in the other two skulls, there was wear on the lower first and second incisors. In all six skulls examined from dogs aged from sixteen to seventeen months, the cusps were worn off the lower first incisor, and in two of these, there was also wear on the cusps of the lower second incisor. Six skulls were examined from dogs aged from seventeen to eighteen months, and in five of these, the cusps were worn off the lower first incisors; however, the cusps were still present on the lower first incisor of the other skull. Five skulls were examined from dogs aged from eighteen to nineteen months. In two skulls, the cusps were worn off the lower first incisor, and in one of these, there was also wear on the cusps of the lower second incisor. In another two skulls, there was some wear on the cusps of the lower first incisor, but in the last skull, the cusps were still well developed.

To summarize these findings in general terms, it was found that the permanent teeth erupt between the age of three and seven months.

After seven months of age, first the cusps of the lower first incisors and later the cusps of the lower second incisors may show signs of wear. Considerable variation was noted, but in approximately fifty-seven per cent of the skulls examined from dogs aged from seven to eleven months, the cusps were worn off the lower first incisors. In the skulls examined from dogs aged from eleven to fifteen months, approximately sixty-seven and one-half per cent showed the cusps worn off the lower first incisors and approximately forty-five and one-half per cent showed some wear on the cusps of the lower second incisors. In the age group fifteen to nineteen months, approximately seventy-seven per cent of the skulls examined had the cusps worn off the lower first incisors and approximately thirty-eight and one-half per cent showed wear on the cusps of the lower second incisors.

Discussion

In this discussion, consideration is given first to the appearance of the ossification centres and then to the union of the epiphyses.

The time of the appearance of the ossification centres has been studied roentgenographically, because this method has the obvious advantage that the ossification process can be followed throughout the growth stages of the animal. Although the number of dogs used was limited, it has been possible to establish more definitely than had been previously determined when the centres appear. This is particularly true for those bones for which the previous available information was either very general or inconclusive, namely the bones of the limbs proximal to the manus and pes, and the bodies of the vertebrae.

One fact which has emerged from this investigation is that the age at which any centre appears is variable. In the dog, the variation is quite marked between animals from certain different breeds, and it is also evident to a lesser degree between animals from the same breed or litter. For example, the ossification centres generally appear at an earlier age in the German shepherd and collie than they do in the beagle or bulldog. There are also obvious individual variations in the collie, which were revealed when the dogs were examined at short intervals during the first month. Pomriaskinsky-Kobozieff and Kobozieff (1954), and Bressou, Pomriaskinsky-Kobozieff, and Kobozieff (1957) have noted similar breed and individual variations of a lesser degree during their study of the manus and pes. The difference in the time of appearance of a centre in animals from different breeds, or from the same breed or litter, is usually less for the centres that appear early in life than it is for those that appear later in life. This difference may have been exaggerated for

the centres that appear later in life, because the interval between examinations was increased as the animals grew older and, therefore, the figures were not so accurate. However, even after allowance has been made for this, it is clear that there is an increase in the difference as the animals grow older. Some variation in the rate of ossification between normal dogs is understandable and to be expected, since, in man, it is well known that there are racial and familial differences in the rate of ossification, and a recent study by Breitbach (1957) has provided further evidence that the beginning of ossification is dependent on hereditary influences. In the sheep, Smith (1956) has ovserved that, in twin and triplet foetuses, ossification is more advanced in the larger foetuses.

Although there are variations in the ages at which the ossification centres appear, the chronological order of appearance of the centres remains fairly constant, granting that there are exceptions particularly amongst the bones of the carpus and tarsus and, in the bulldog, between the epiphyses of the metatarsal bones and the proximal phalanges. Sex does not seem to influence the ossification process in the dog as it does in the primates, in the rat, and, perhaps, in the sheep. The findings of this study show that the ossification process is sometimes more advanced in the male, but that the reverse may also be found (tables 5,14,34). However, the differences, when they occur, are slight, and the evidence is inconclusive, because a large scale investigation would be required to determine the influence of sex on the rate of ossification. Pomriaskinsky-Kobozieff and Kobozieff (1954), and Bressou, Pomriaskinsky-Kobozieff, and Kobozieff (1957) were inclined to the view that the ossification process was more

advanced in the male, but they likewise admitted that their evidence was inconclusive. If it should subsequently be shown that in the dog, the rate of ossification is more advanced in the male than in the female, it will open up an interesting field of study, because, in the primates and the rat, it has been observed that the ossification process is more advanced in the female. Amongst others, Pryer (1908, 1916, 1923), Menees and Holly (1932), Francis, Werle, and Behm (1939), Hill (1939), and Pyle and Sontag (1943) have noted, in man, that the ossification process is more advanced in the female than in the male. Similar observations have been made for the chimpanzee by Nissen and Riesen (1949), for the Rhesus monkey by van Wagenen and Asling (1958), and for the rat by Spark and Dawson (1928). In the sheep, Smith (1956) observed that if twin and triplet foetuses were of the same size, the ossification process was more advanced in the female, although, as mentioned earlier, if the foetuses were of different sizes, the ossification process was more advanced in the larger foetuses.

No attempt was made to determine the effect of the level of nutrition on the rate of ossification, but an opportunity was afforded to observe the effect of an interference in the level of nutrition and the health of the animal. In the litter of beagles, three of the six pups had a heavy infestation of helminths as a result of which two succombed in the twenty-fifth day. The third pup survived, but its ossification process was retarded (fig.48). The retardation is not always evident from the tables, since a particular centre, or centres, could appear in all the pups during an interval between examinations, although it would be less well developed in the affected pup. In man, it is well known that malnutrition or a debilitating illness will retard the rate of the ossification process, and, in the

rat, Acheson and Macintyre (1958) have shown that the rate of ossification can be retarded by starvation or an acute infection.

In several epiphyses, the ossification process has been seen to start simultaneously from two points. The epiphyses in which this has been observed are the olecranon and distal epiphysis of the ulna, the distal epiphysis of the fibula, and the epiphysis of the fibular tarsal bone. Schaeffer (1934), Pomriaskinsky-Kobozieff and Kobozieff (1954), and Bressou, Pomriaskinsky-Kobozieff, and Kobozieff (1957) have also noted that ossification sometimes starts simultaneously at more than one point. Francis, Werle, and Behm (1939) have noted a similar occurence in man and have attributed it to an asymptomatic form of osteochondrosis. When ossification starts at more than one point, the points are normally situated close together and usually unite shortly after they appear. If, however, the points failed to fuse at an early date, it would appear as though there were two centres of ossification. This may account for the fact that the author, like Schaeffer (1934), has been able to demonstrate only one centre of ossification for the proximal extremity of the humerus either roentgenographically or by staining and then clearing the bone; whereas Lesbre (1897), Ellenberger and Baum (1943), and Seoudi (1948) consider that there is a separate centre for the greater tubercle. Failure of separate points of ossification to unite and form a single centre of ossification probably accounts for such clinical entities as a bipartite patella, or an accessory centre at the head of the radius such as that noted by Cawley and Archibald (1959).

The ages at which the various epiphyses unite are undoubtedly of more interest and importance to the clinician than the ages at which the centres of ossification appear. Epiphyseal union has

been studied roentgenographically and on the macerated skeleton. The former method enables the process to be followed in the live animal, and the latter method provides concrete supporting evidence for the roentgenographic findings. As a result, it has been possible to establish more definite age periods for epiphyseal union in the bones of the limbs and the bodies of the vertebrae than had been previously established.

Prior to this study, the information available on the age at which epiphyseal union occurred was limited and, for some of the centres and epiphyses, it was based on the findings of only one or two workers or groups of workers. For example, Schaeffer (1934), who had very few dogs on which to base his findings, was the only previous worker to have determined an age for the following:- the union of the capitulum and lateral part of the trochlea of the humerus with the medial part of the trochlea; the union of the medial epicondyle of the humerus with the trochlea; and the union of the symphyseal rami of the pubis and ischium. Schaeffer (1934), and Seoudi (1948) were the only previous workers to have given an age for the union of the proximal epiphysis of the fibula with the diaphysis. Schaeffer (1934), and Pomriaskinsky-Kobozieff and Kobozieff (1954) had provided the only previous information regarding the union of the centres of the radial, intermediate, and central carpal bones and the union of the epiphysis of the accessory carpal bone with the body of the bone. Schaeffer (1934), and Bressou, Pomriaskinsky-Kobozieff, and Kobozieff (1957) were the only workers to have given an age for the union of the distal epiphysis of the fibula with the diaphysis and their findings were not in accord; and the latter group had provided the only information regarding the union of the medial malleolus with the

distal epiphysis of the tibia. Finally, Lesbre was the only previous worker to have given information regarding the union of the epiphyses with the bodies of the vertebrae.

The findings of this study show clearly that there is considerable variation in the age at which a particular epiphysis unites in different dogs, although the chronological order of epiphyseal union remains fairly constant. The variation occurs between litter mates, dogs of the same breed, and dogs of different breeds: for example, in the litter of collies X-rayed at two hundred and seventy-seven days of age, one of the dogs, a female, shows complete epiphyseal union at the distal extremity of the femur and proximal end of the tibia, whereas the other three dogs, a male and two females, do not show complete epiphyseal union (fig.51a,b,c); and in the tables of the roentgenographic findings, differences can be noted for the time of epiphyseal union between the collies and German shepherds. In view of the number of different factors that can influence bone growth and skeletal maturation, reviewed by Sissons (1956), it is not surprising that these variations occur in apparently normal, healthy animals. In fact, a recent survey of young American males by McKern and Stewart (1957) has shown that there is considerable variation in the age at which particular epiphyses unite, much more than had previously been thought. Judging by the skeletal material available for study, there does not appear to be any relationship between the differences that occur in the age of epiphyseal union and the single factor dominant character for achondroplasia. Sex does not appear to influence the rate of epiphyseal union in the dog as it does in man and the Rhesus monkey, but again it would require a much more extensive investigation than carried out here to determine the influence of sex, if any, on the rate of skeletal maturation. In man,

it has been recognized for some time that epiphyseal union takes place earlier in the female than in the male, and the fact has been analyzed by Greulich and Pyle (1959), and Pyle and Hoerr (1955). In the Rhesus monkey, van Wagenen and Asling (1958) have shown that epiphyseal union takes place earlier in the female than in the male.

It was mentioned in the introduction that the ages given by Lesbre (1897) for epiphyseal union in some of the bones of the limbs had not been substantiated by subsequent workers. A comparison of the age periods established in this study with the ages given by Lesbre (tables 1,47) shows that up to the age of about seven months the differences are small and can be explained on the basis of individual and breed variations. After the age of seven months, however, there are marked discrepancies between the ages established in this study and those given by Lesbre, except for the age at which the proximal epiphysis of the humerus unites with the diaphysis. A further comparison of the age periods established in this study with the ages given by Schaeffer (1934), Seoudi (1948), or Schlotthauer and Janes (1952) shows that, in general, the differences are small and can again be explained on the basis of individual or breed variations. The weight of evidence indicates therefore, that, for some reason, the ages given by Lesbre for those epiphyses that unite after the animal has reached the age of approximately seven months are inaccurate and place the time of union, on an average, five to seven months later than it should be. It is very doubtful whether this discrepancy can be accounted for by normal individual or breed variations. One possible explanation is that the rate of skeletal maturation was retarded for one reason or another in all the dogs that Lesbre used. For example, Sellheim(1899), and Tausk and

Fremery (1935) have shown that epiphyseal union is markedly delayed in dogs which have been spayed early in life. Another possible explanation is that Lesbre had incorrectly assessed the age of the dogs which he used, since he himself has stated that the ages were estimated by the teeth and should be considered approximate. Although there is no way of telling the state of the dogs which Lesbre used, it is possible, fortunately, to be fairly certain of the criteria that he used for estimating the age of the dogs by the teeth.

Cornevin and Lesbre (1894) stated that from birth to seven months, the age could be estimated first by the eruption and wear on the deciduous incisors and then by the eruption of the permanent teeth, and that after seven months, the age could be estimated by the appearance of the incisors and the wear on their crowns. The following guides were given:- at one year, the teeth are very white and do not show any wear; at fifteen months, the lower first incisors are in wear; and at eighteen months, the lower first incisors are worn level and the lower second incisors are in wear (fig.49). Prior to 1894, several other works on the estimation of the age by the teeth had been published. Girard (1834), Moussu (1890), Huidekoper (1891), and Liautard (1892) had given criteria that were essentially the same as those of Cornevin and Lesbre, and so it is fairly certain that these were the accepted criteria of the day and the ones which Lesbre would use.

The findings of this study indicate that all the permanent teeth have erupted by seven months of age and that wear can be expected on the cusps of the lower first incisors at any time after seven months. They further show that both the amount of wear and the number of dogs showing wear increase steadily as the age increases.

Boenisch (1913) studied the incisor teeth in a total of one hundred and twenty-five dogs of known ages, of which fourteen were between the age of six and eighteen months. He found that the permanent teeth had erupted by six months and that the cusps were worn off the lower first incisors between six and eighteen months. Kroon (1929) stated that the permanent teeth have erupted by the sixth or seventh month and that the cusps are worn flat on the lower first incisor between six and eighteen months (fig.50). In the author's opinion, after the age of seven months any estimate of the age of the dog by the teeth is liable to be inaccurate, because the amount of wear that has taken place depends on the hardness of the teeth, the type of food, and the habits of the dog.

If the criteria established by Cornevin and Lesbre for the amount of wear on the incisor teeth between six and eighteen months are compared with either the findings of this study or the criteria described by Boenisch or by Kroon, it becomes clear that the amount of wear that Cornevin and Lesbre expected to find at fifteen months can in fact be found at any time after the age of seven months, and that Cornevin and Lesbre did not expect to find the cusps worn off the lower first incisors and wear on the lower second incisors until eighteen months (fig.49$\frac{2}{2}$), whereas this amount of wear can frequently be found on the teeth of dogs over eleven months of age (fig.47b,c,d,e).

The author believes that this difference of opinion regarding the criteria for estimating the age by the teeth offers a more likely explanation for the discrepancies that exist between the ages given by Lesbre and the age periods established by this study, than the possibility that in all the dogs examined by Lesbre the ossification process had been retarded.

There is, however, one exception. As mentioned before, Lesbre has given the age for the union of the proximal epiphysis of the humerus as thirteen months. This falls within the age period established in this study and corresponds with the findings of Schaeffer, and Seoudi. Why then should Lesbre's findings correspond for this one epiphysis? The only explanation that the author has to offer is that it was due to a copying error, since Lesbre stated in the part of his paper dealing specifically with the humerus that the proximal epiphysis united with the diaphysis at eighteen months, whereas in the table summarizing his findings at the end of the paper the age of union is given as towards thirteen months. If Lesbre really intended the figure to be eighteen months, then the proximal epiphysis of the humerus would fit into the rest of the pattern.

Bressou, Pomriaskinsky-Kobozieff, and Kobozieff (1957) have stated that union of the distal epiphyses of the tibia and fibula with their respective diaphyses does not take place until the fifteenth or eighteenth month. Their findings were based on the examination of dogs brought into a small animal hospital. Although it is possible for this union to be delayed until the fifteenth or eighteenth month, this study has shown quite conclusively that it frequently occurs much earlier.

The age period established by this study for the union of the ossa coxarum is lengthy, because complete union was not considered to have occured until the two bones were completely united by bone.

Finally, with regard to the union of the epiphyses of the bodies of the vertebrae, Lesbre (1897) stated that union starts in the caudal thoracic region, continues into the lumbar region, and terminates in the cervical region at the age of one and one-half to two years.

Addendum

Since this thesis was completed, Smith and Allcock (1960) have published their findings for the ages of epiphyseal union in the limbs of the greyhound. Twenty-eight dogs from six litters were x-rayed at intervals from thirteen weeks. Their findings correspond with the findings of this study and, therefore, add further support to the view that the ages given by Lesbre were incorrect for those epiphyses that unite after the age of seven months.

Smith, R. N., and Allcock, J. (1960). Epiphysial Fusion in the Greyhound, Vet. Rec. 72, 75-79.

This study has shown that union starts in the caudal coccygeal region, continues in the cervical, sacral and lumbar regions, and terminates in the mid-thoracic region some time between the eleventh and the fourteenth month. Again it can be seen that there is a difference of about five to seven months between the age given by Lesbre and the age established by this study.

Conclusions

In conclusion it can be stated that:

(1) although the centres of ossification usually appear in the same chronological order, the ages at which they appear vary. The variations are present between litter mates and individuals of the same breed, and to a greater extent between individuals of different breeds.

(2) the ages at which epiphyseal union takes place also vary, although the chronological order of union again remains fairly constant. The variations can be seen between litter mates and individuals of the same breed, and to a greater extent between individuals of different breeds. Judging by the limited amount of material available for study, the presence of the single factor dominant character for achondroplasia does not appear to affect the age of epiphyseal union.

(3) sex does not appear to influence the rate of skeletal maturation judging by the material available for study.

(4) after the age of seven months, the ages at which the epiphyses actually unite differ quite markedly from the ages given by Lesbre (1897) and generally accepted by veterinary anatomists. The age of the dogs studied by Lesbre had been estimated by the teeth, and, in all probability, this difference in opinion about the time of epiphyseal union is due to the fact that the criteria for estimating the age by the amount of wear on the incisor teeth, which had been described by Cornevin and Lesbre(1894) and were generally accepted at that time, were inaccurate and misleading as to the amount of wear that is present on the incisor teeth after the age of seven months: after the age of seven months, the amount of wear on the lower incisors may vary greatly and is usually in excess of that described by Cornevin and Lesbre.

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Figure 1. Mediolateral view of the shoulder of a 52-day-old male bulldog.

(a) centre of ossification for the scapular tuberosity.
(b) proximal epiphysis of the humerus.

Figure 2. Mediolateral view of the shoulder of an 158-day-old collie. The scapular tuberosity is completely united with the body of the scapula.

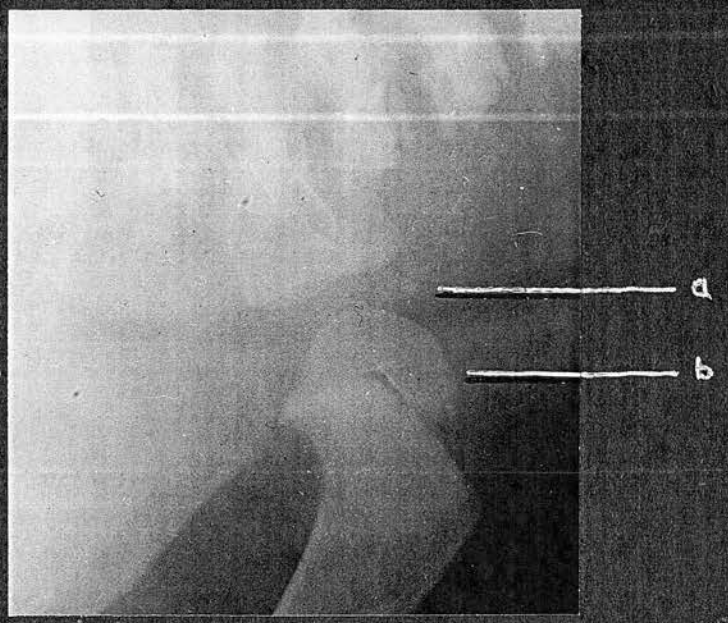


Fig. 1

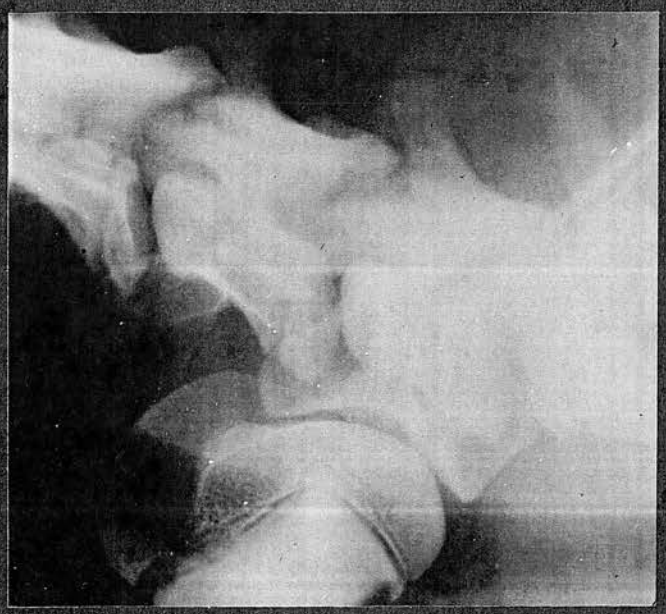


Fig. 2

Figure 3. Lateral view of the arm of a 10-day-old female German shepherd.

(a) centre of ossification for the proximal epiphysis of the humerus.
(b) centres of ossification for the capitulum and lateral part of the trochlea and for the medial part of the trochlea of the humerus.

Figure 4. Mediolateral view of the arm of a 10-day-old female German shepherd.

(a) centre of ossification for the proximal epiphysis of the humerus.
(b) centres of ossification for the capitulum and lateral part of the trochlea and for the medial part of the trochlea of the humerus.

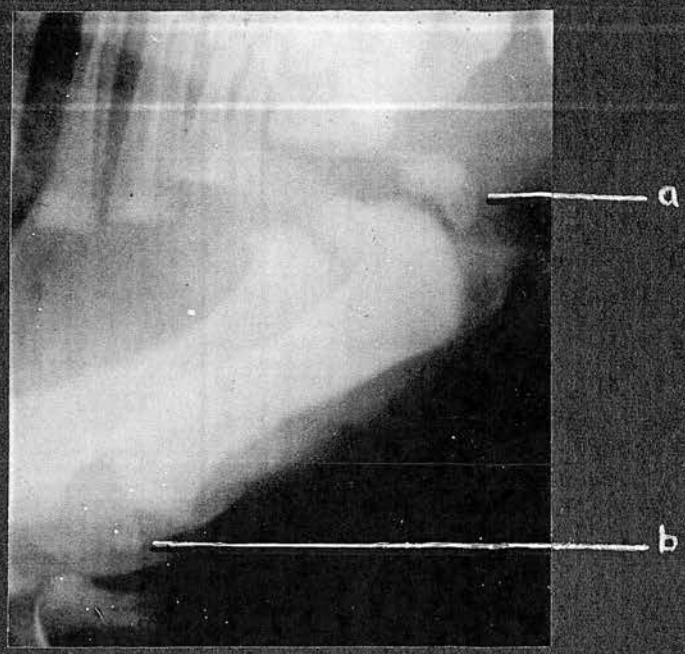


Fig. 3

Fig. 4

Figure 5. Mediolateral view of the elbow of a 46-day-old female German shepherd.

(a) capitulum and lateral part of the trochlea of the humerus.
(b) centre of ossification for the medial epicondyle of the humerus.
(c) centre of ossification for the olecranon of the ulna.
(d) medial part of the trochlea of the humerus.
(e) proximal epiphysis of the radius.

Figure 6. Mediolateral view of the pectoral limb of a 23-day-old male collie.

(a) centre of ossification for the proximal epiphysis of the radius.
(b) centre of ossification for the distal epiphysis of the radius.
(c) centre of ossification for the intermediate carpal bone.
(d) centre of ossification for the first carpal bone.
(e) centre of ossification for the body of the accessory carpal bone.
(f) centre of ossification for the fourth carpal bone.

Fig. 5

Fig. 6

Figure 7. Mediolateral view of the elbow of a 287-day-old female German shepherd. It shows the proximal epiphysis of the radius completely united with the diaphysis. Note that the surface of the bone is smooth and that the trabeculae are passing from the diaphysis into the epiphysis along the entire length of the epiphyseal line.

Figure 8. Mediolateral view of the distal end of the radius and ulna of a 357-day-old female German shepherd. It shows the distal epiphysis of the radius completely united with the diaphysis. Note that the surface of the bone is smooth and that the trabeculae are passing from the diaphysis into the epiphysis along the entire length of the epiphyseal line.

Fig. 7

Fig. 8

Figure 9. (a) Lateral view of the right ulna of skeleton (125) aged seven months. It shows the olecranon completely united with the diaphysis.

(b) Medial view of the left humerus of skeleton (977) aged eleven and one-half months. It shows stage "3" union of the proximal epiphysis with the diaphysis. Note the break in the surface of the bone between the epiphysis and the diaphysis, which is marked by arrows.

(c) Lateral view of the right humerus of skeleton (125) aged seven months. It shows the distal epiphysis completely united with the diaphysis.

Figure 10. Lateral view of the right pectoral limb of skeleton (1698) aged eleven and one-half months. It shows the proximal and distal epiphyses of the humerus, radius, and ulna completely united with their respective diaphyses.

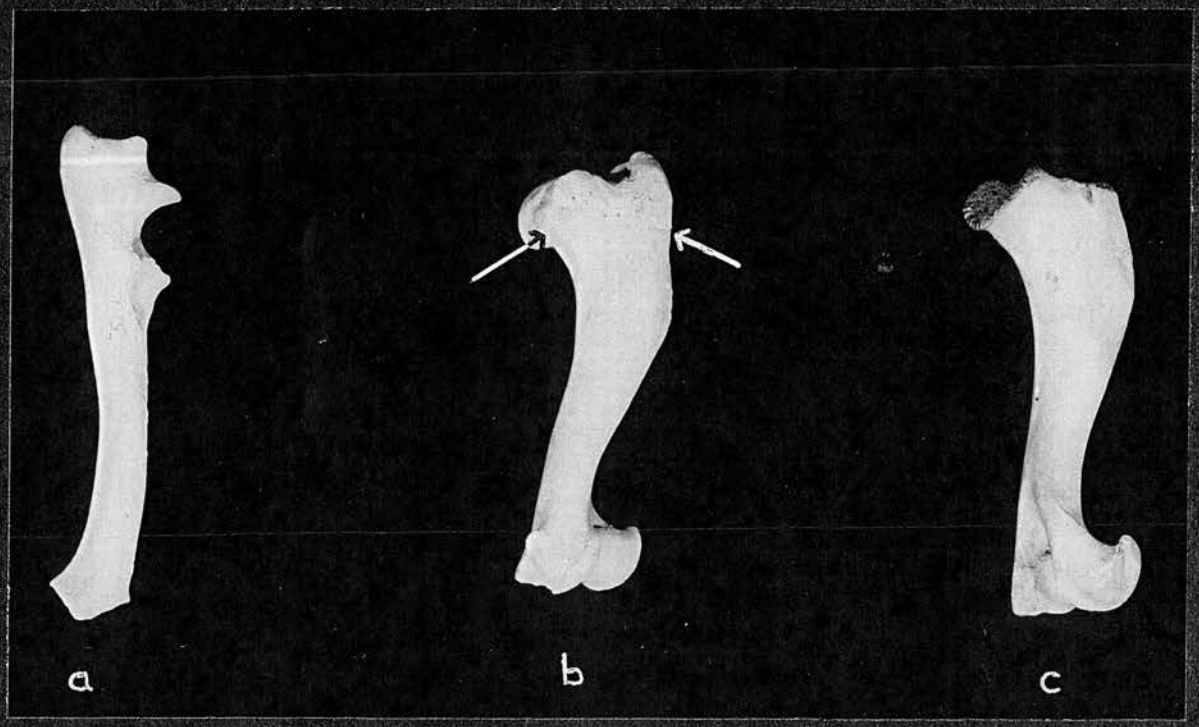


Fig. 9

Fig. 10

Figure 11. (a) Caudal view of the right radius of skeleton (652) aged ten and one-half months. It shows the proximal and distal epiphyses completely united with the diaphysis.

(b) Lateral view of the left ulna of skeleton (652) aged ten and one-half months. It shows the olecranon and distal epiphysis completely united with the diaphysis.

Figure 12. Mediolateral view of the distal end of the radius and ulna of skeleton (652). The distal epiphyses are completely united with their respective diaphyses as shown in figure 11. Note that the epiphyseal line persists in the radius even though union is complete.

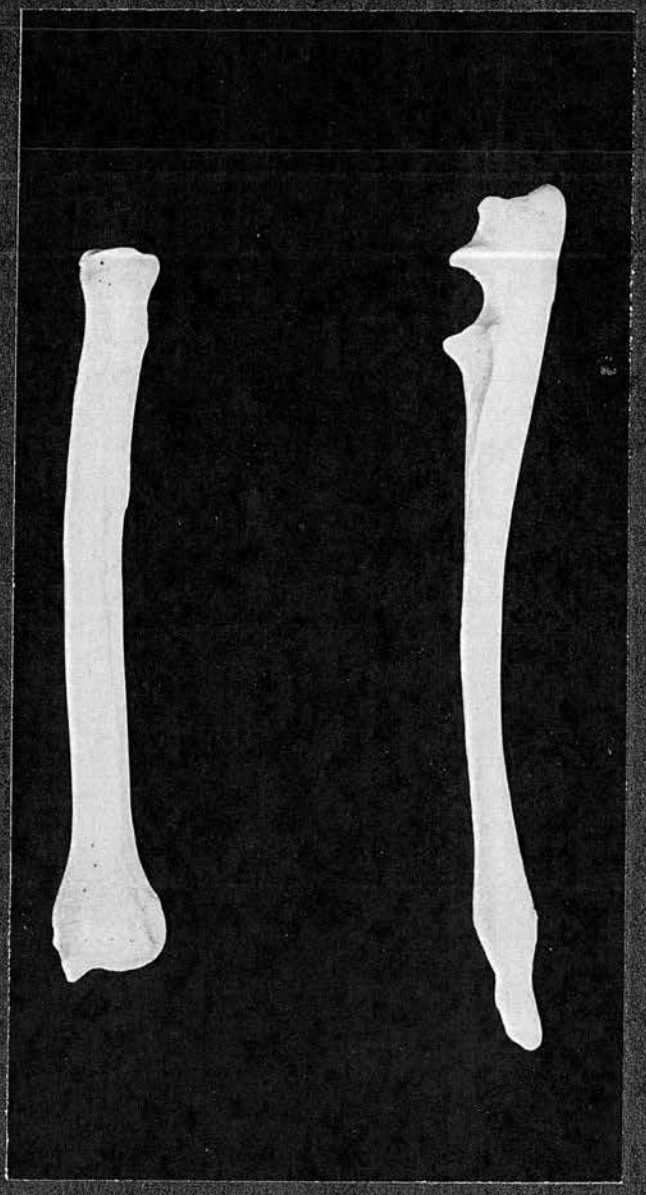


Fig. 11

Fig. 12

Figure 13. Mediolateral view of the elbow of a 249-day-old male collie. The distal epiphysis of the humerus is completely united with the diaphysis. The olecranon of the ulna is united with the diaphysis although a faint line of decreased density, representing the line of union, can still be seen. Note the slight break in the surface of the radius between the proximal epiphysis and the diaphysis which indicates that union here is not quite complete.

Figure 14. Dorsovolar view of the distal end of the radius and ulna and the carpus of a 277-day-old female collie. The distal epiphysis of the ulna is completely united with the diaphysis.

Fig. 13

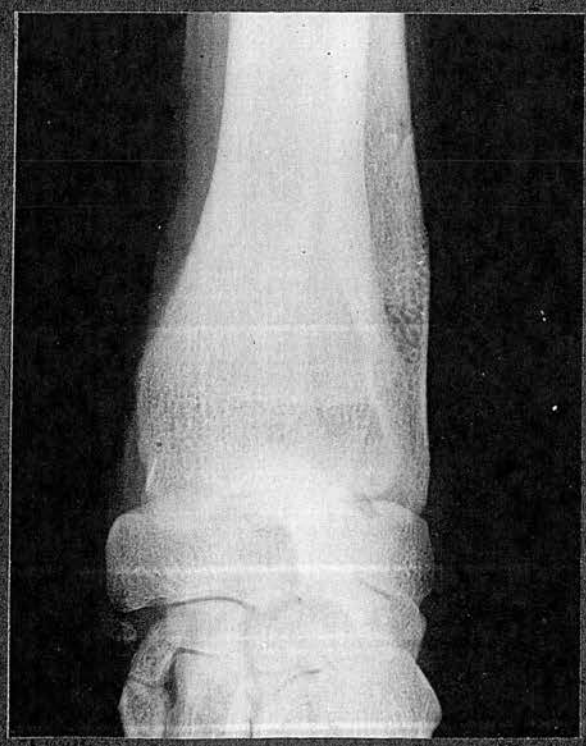


Fig. 14

Figure 15. Lateral view of the right pectoral limb of (a) skeleton (1847) aged nine months, and (b) skeleton (1359) aged ten months. In each limb, note that all the epiphyses are completely united with their respective diaphyses, with the exception of the proximal epiphysis of the humerus which has not yet united.

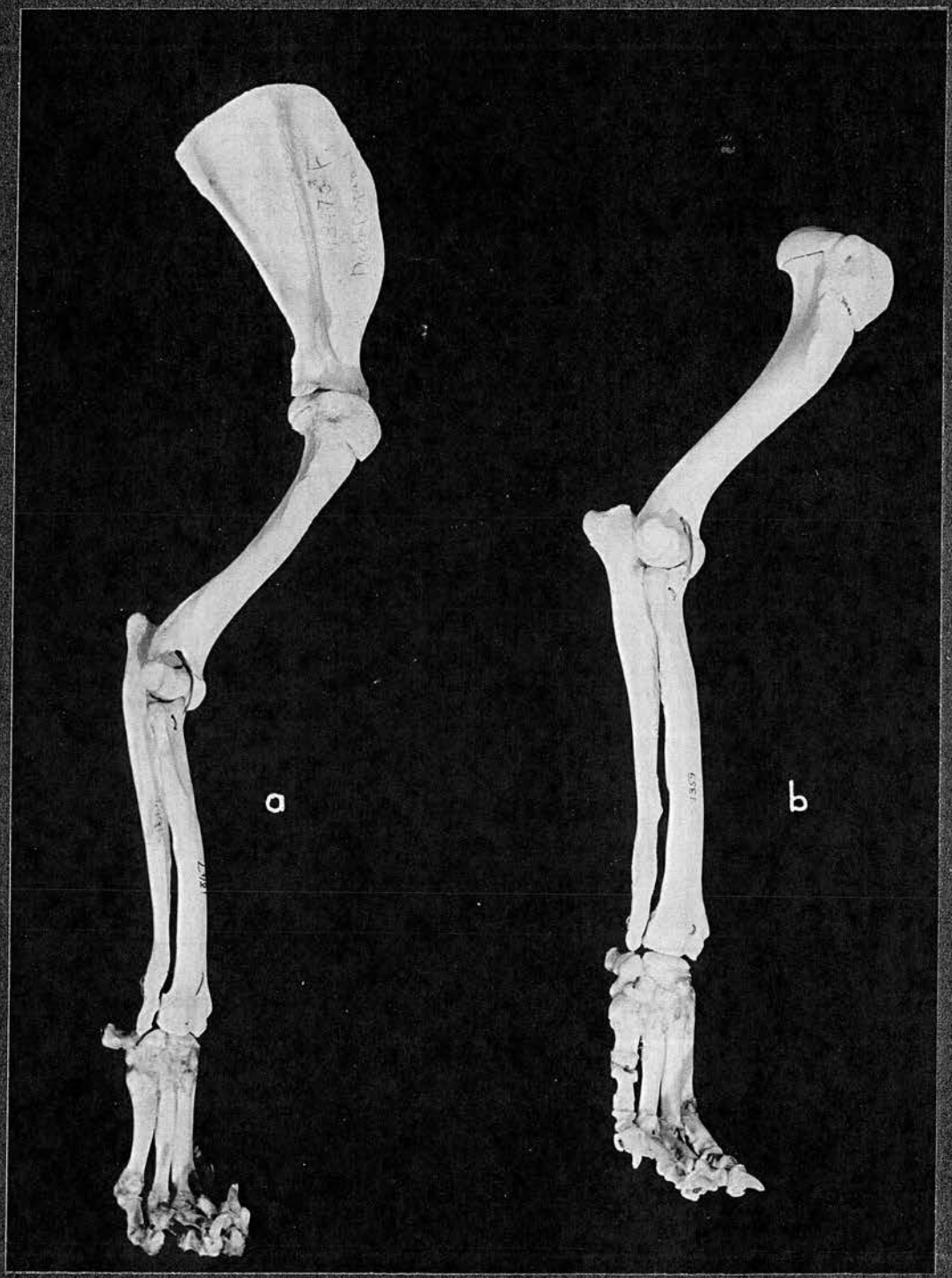


Fig. 15

Figure 16. Lateral view of the right pectoral limb of (a) skeleton (1700) aged ten months, (b) skeleton (1746) aged ten and one-half months, (c) skeleton (1633) aged twelve months, and (d) skeleton (1747) aged thirteen months. In each limb, the distal epiphysis of the humerus, the proximal and distal epiphyses of the radius, and the olecranon and distal epiphysis of the ulna are completely united with their respective diaphyses. The proximal epiphysis of the humerus has not united with the diaphysis in (a) and is in stage "3" union in (b), (c), and (d).

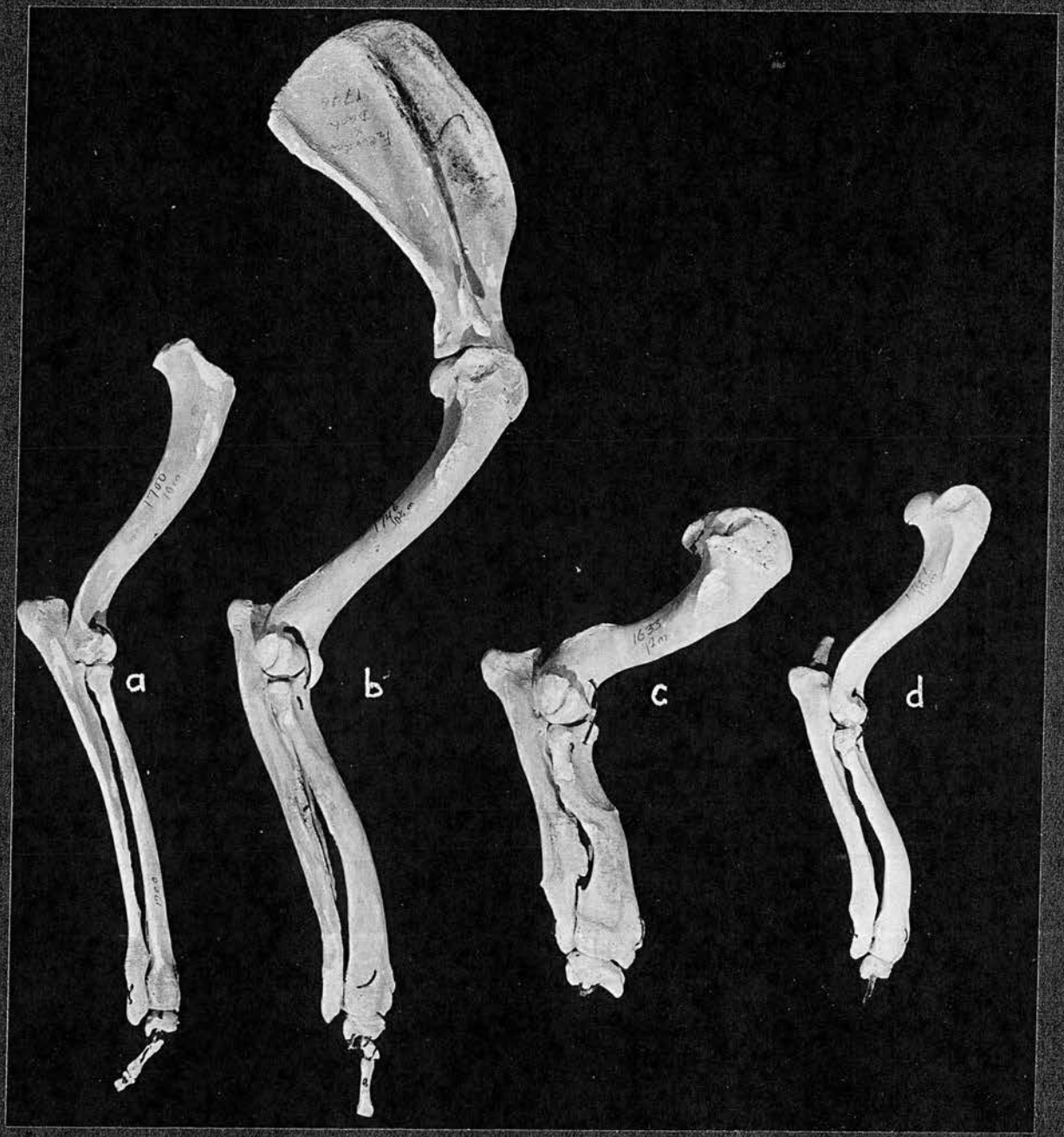


Fig. 16

Figure 17. Mediolateral view of the pectoral limb of a 55-day-old female collie.

(a) centre of ossification for the olecranon of the ulna.
(b) centre of ossification for the distal epiphysis of the ulna. Note that its development is more advanced than that of the olecranon.
(c) epiphysis of the accessory carpal bone.
(d) ulnar carpal bone.
(e) fourth carpal bone.
(f) radial, intermediate, and central carpal bones.
(g) second carpal bone.
(h) third carpal bone.

Figure 18. Mediolateral view of the carpus of an 118-day-old female collie. It shows the epiphysis of the accessory carpal bone completely united with the body of the bone.

Fig. 17

Fig. 18

Figure 19. (a) Distal view of the right scapula of skeleton (133) aged six months. It shows the scapular tuberosity completely united with the body.

(b) Distal view of the left humerus of skeleton (1748) aged two and one-half months. It shows that the line of union between the medial and lateral parts of the trochlea lies sagittally in the groove of the trochlea.

(c) Lateral view of the medial malleolus of skeleton (174) aged three and one-half months. It shows the centre for the medial malleolus uniting with the distal epiphysis.

(d) Medial view of the distal epiphysis of the left humerus of skeleton (275) aged four and one-half months. It shows the medial epicondyle completely united with the medial part of the trochlea.

(e) Proximal view of the fused radial, intermediate, and central carpal bones of skeleton (174) aged three and one-half months. Compare this view with the distal view in figure 20c.

Figure 20. (a) Proximal view of the distal epiphysis of the right tibia of skeleton (125) aged seven months. It shows trabeculae which pass from the epiphysis to the diaphysis over about one-half of the union as in stage "2" union. (The epiphysis was eased off the diaphysis to show this.)

(b) Lateral view of the accessory carpal bone of skeleton (381) aged four months. It shows the epiphysis completely united with the body.

(c) Distal view of the radial, intermediate, and central carpal bones of skeleton (174) aged three and one-half years. Note that on this surface, union between the radial and intermediate carpal bones is not quite complete. Compare this view with the proximal view shown in figure 19e.

(d) Proximal view of the proximal extremity of the left femur of skeleton (125) aged seven months. It shows the union of the head with the trochanter major, which takes place prior to the union of the proximal epiphysis with the diaphysis.

(e) Proximal view of the proximal extremity of the left tibia of skeleton (125) aged seven months. It shows the union of the tibial tuberosity with the condyles, which takes place prior to the union of the proximal epiphysis with the diaphysis.

(f) Distal view of the distal epiphysis of the left humerus of skeleton (174) aged three and one-half months. It shows the medial part of the trochlea united with the lateral part and the capitulum.

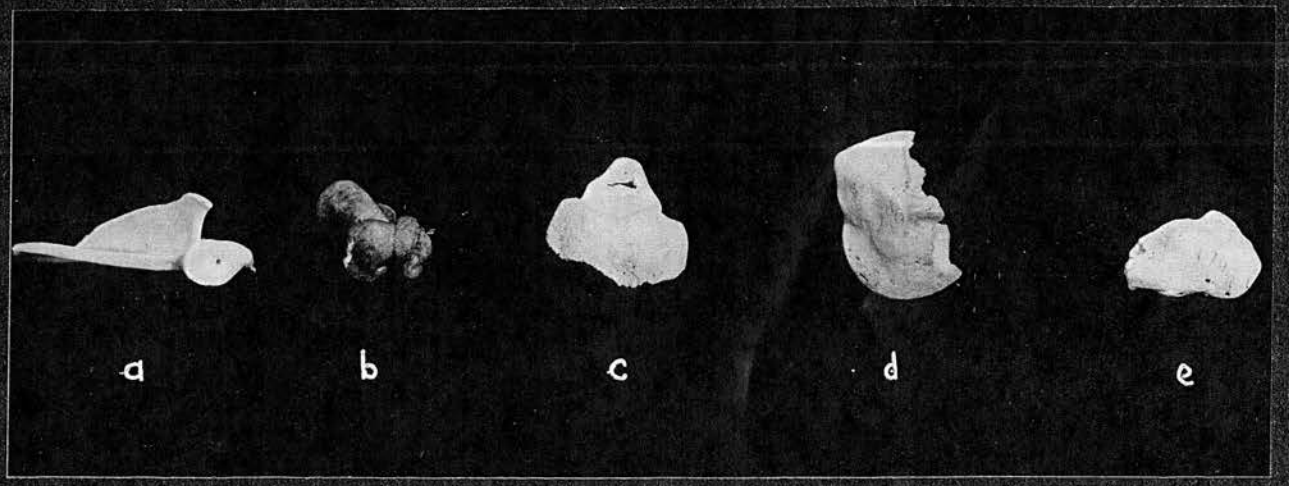


Fig. 19

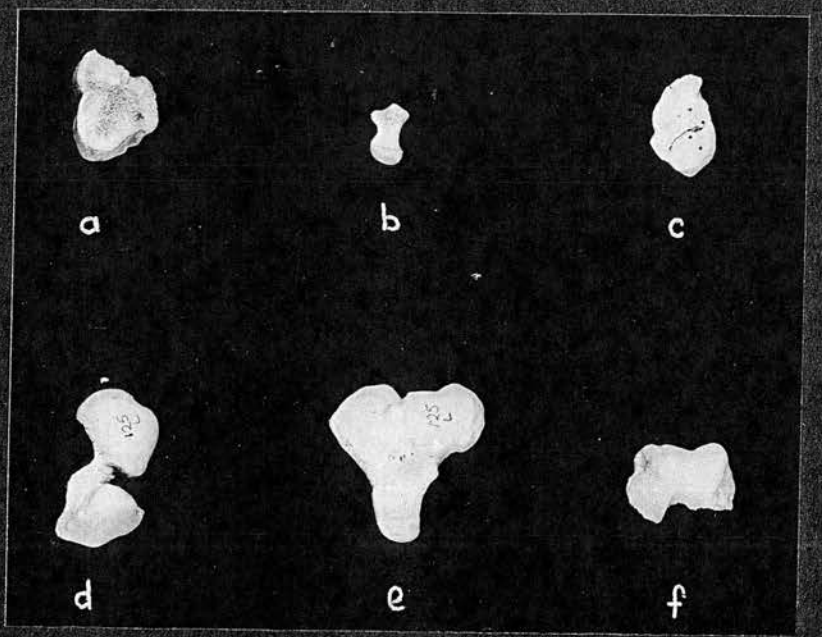


Fig. 20

Figure 21. Ventrodorsal view of the coxofemoral articulation of a 55-day-old female collie.

(a) centre of ossification for the os acetabulum.

Figure 22. Ventrodorsal view of the pelvis of a 69-day-old female collie.

(a) centre of ossification for the sciatic tuber, just appearing.

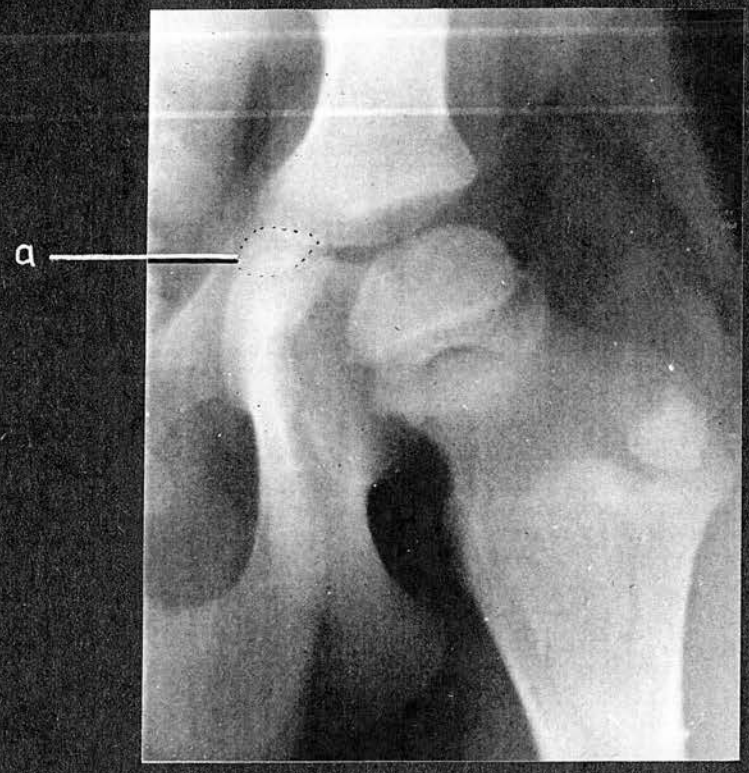


Fig.21

Fig.22

Figure 23. Lateral view of the pelvis of an 132-day-old female collie.

(a) centre of ossification for the crest of the ilium.
(b) centre of ossification for the interischial bone.

Figure 24. Lateral view of the pelvis of an 162-day-old female German shepherd.

(a) centre of ossification for the interischial bone.

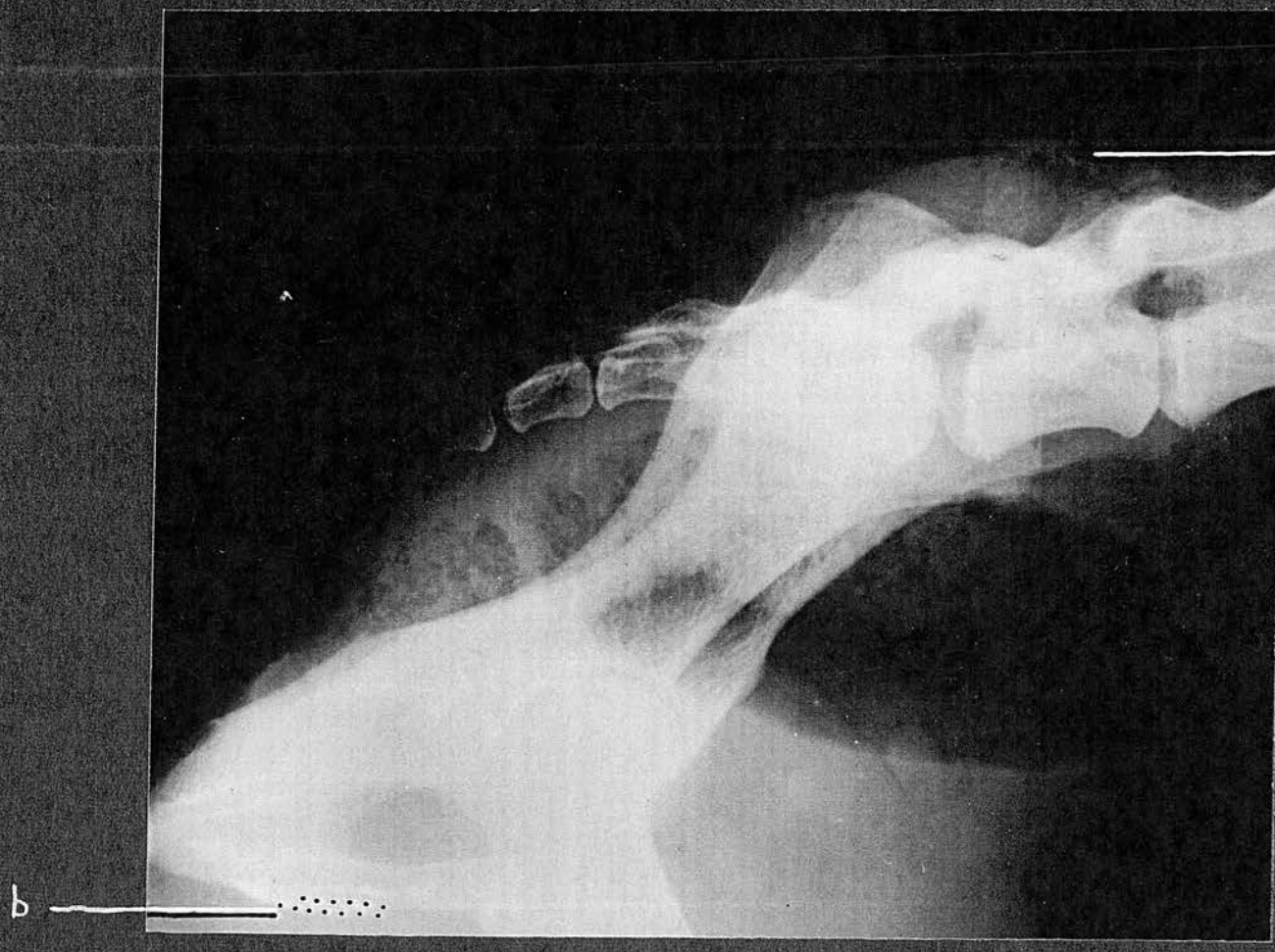


Fig.23

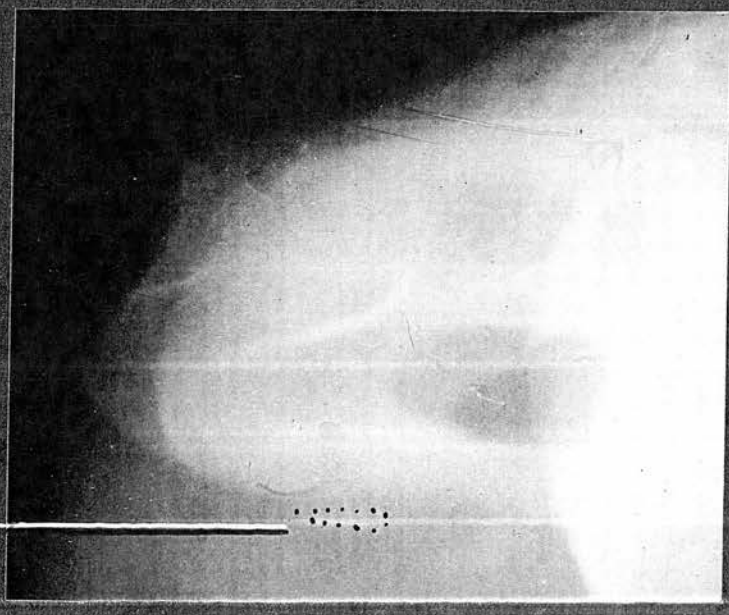


Fig.24

Figure 25. Dorsal view of the right os coxae of skeleton (381) aged four months. It shows that the os acetabulum, the ischium, and the pubis unite with each other before they unite with the ilium. The pubis is in stage "3" union with the ischium.

(a) os acetabulum.

Figure 26. Ventrodorsal view of the pelvis of an 158-day-old female collie.

(a) centre of ossification for the ischial arch.
(b) centre of ossification for the sciatic tuber.

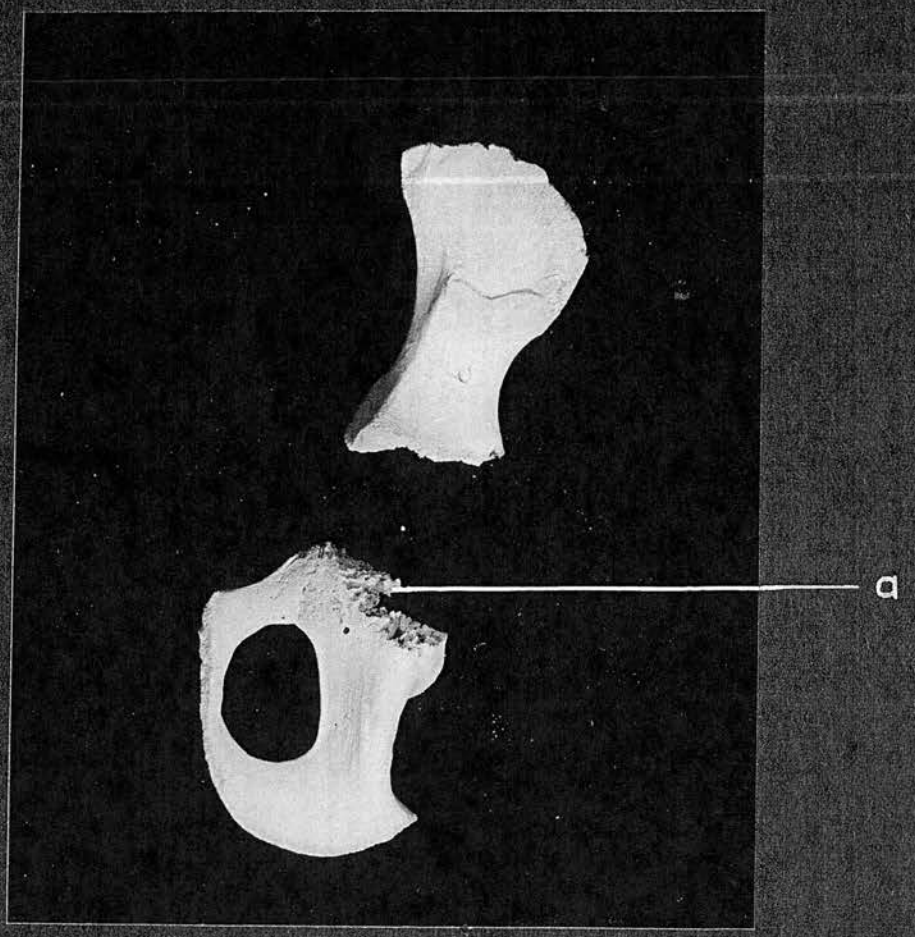


Fig. 25

Fig. 26

Figure 27. (a) Dorsal view of the left os coxae of skeleton (275) aged four and one-half months. It shows stage "3" union of the ilium with the ischium and pubis.

(b) Dorsal view of the right os coxae of skeleton (977) aged eleven and one-half months. It shows the sciatic tuber and ischial arch completely united with the ischium.

(c) Dorsal view of the right os coxae of skeleton (652) aged ten and one-half months. It shows the sciatic tuber completely united and the ischial arch uniting with the ischium.

Figure 28. Mediolateral view of the right femur of a 13-day-old male collie.

(a) centre of ossification for the distal epiphysis of the femur.
(b) centre of ossification for the condyles of the tibia.
(c) centre of ossification for the fourth tarsal bone.
(d) centre of ossification for the head of the femur.
(e) centre of ossification for the central tarsal bone.

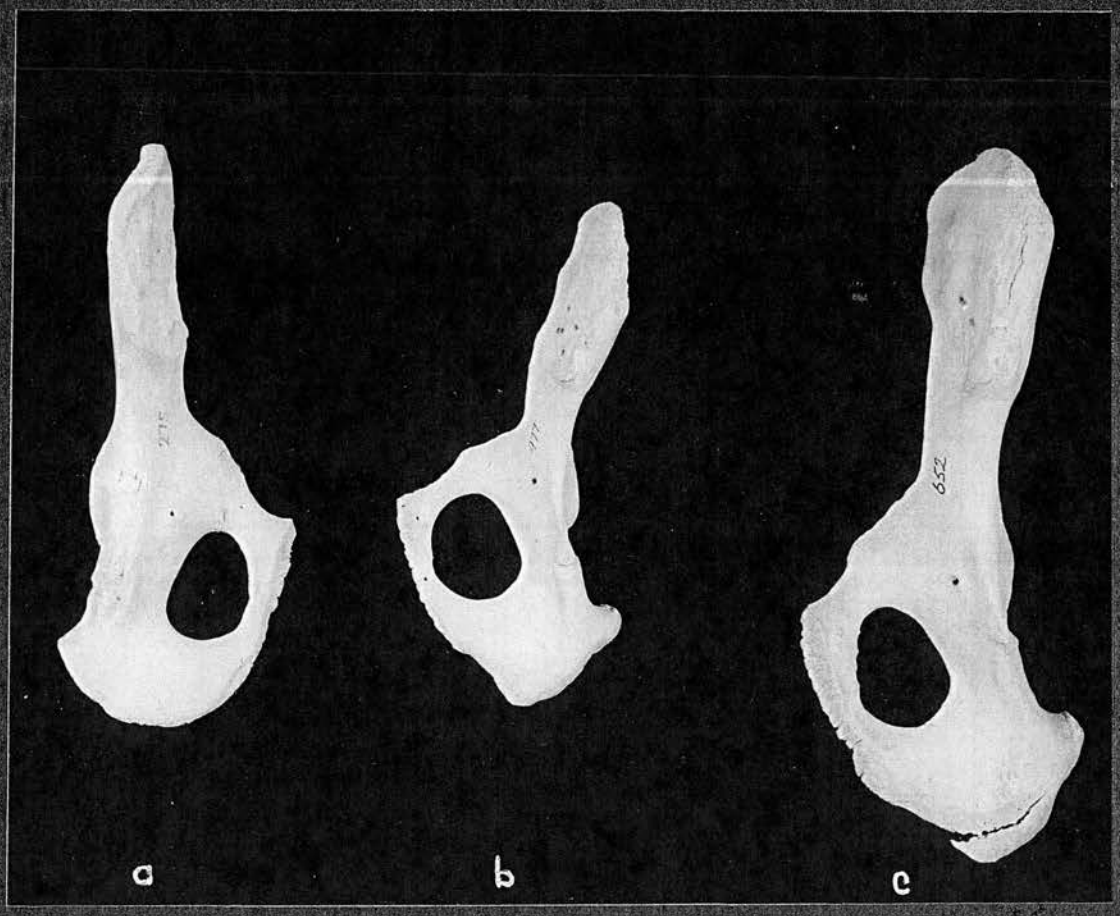


Fig. 27

Fig. 28

Figure 29. Ventrodorsal view of the proximal end of the right femur of a 55-day-old male collie.

(a) centre of ossification for the trochanter major.
(b) centre of ossification for the trochanter minor.

Figure 30. Ventrodorsal view of the proximal extremity of the left femur of a 259-day-old female German shepherd. It shows a spur of bone (a) growing from the trochanter major toward the head. Compare this figure with figure 20d.

Fig.29

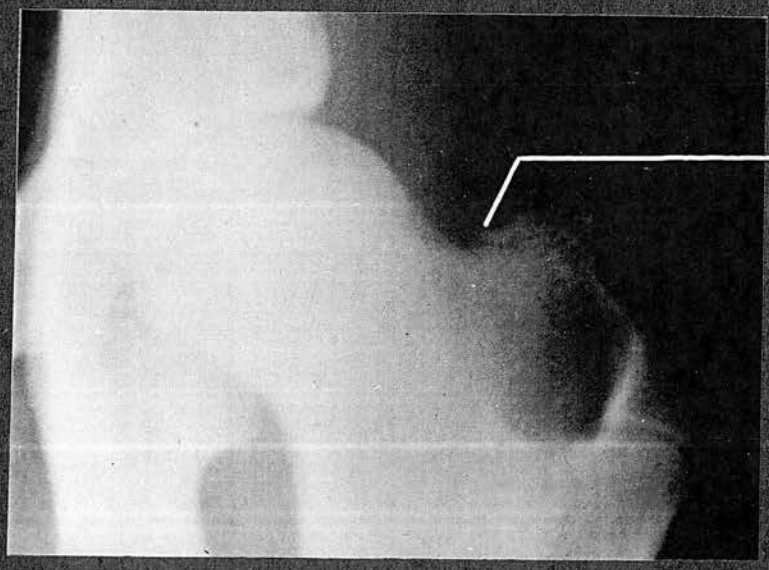


Fig.30

Figure 31. Ventrodorsal view of the proximal end of the left femur of a 320-day-old female German shepherd. It shows the head and trochanter major completely united with the diaphysis, and the sciatic tuber completely united with the ischium.

Figure 32. Mediolateral view of the right stifle of a 320-day-old female German shepherd. It shows complete union of the distal epiphysis of the femur with the diaphysis.

Fig.31

Fig.32

Figure 33. (a) Cranial view of the right femur of skeleton (1359) aged ten months. It shows the epiphyses completely united with the diaphysis. Compare this figure with figure 34.

(b) Cranial view of the right femur of skeleton (977) aged eleven and one-half months. It shows the epiphyses completely united with the diaphysis.

(c) Lateral view of the right femur of skeleton (652) aged ten and one-half months. It shows stage "3" union of the trochanter major and distal epiphysis with the diaphysis. Compare this figure with figure 41.

Figure 34. Mediolateral view of the right pelvic limb of skeleton (1359) aged ten months. It shows the distal epiphysis of the femur, the proximal epiphysis of the fibula, and the distal epiphysis of the tibia completely united with their respective diaphyses; and it shows stage "3" union of the proximal epiphysis of the tibia with the diaphysis. Compare this figure with figures 33a and 37c.

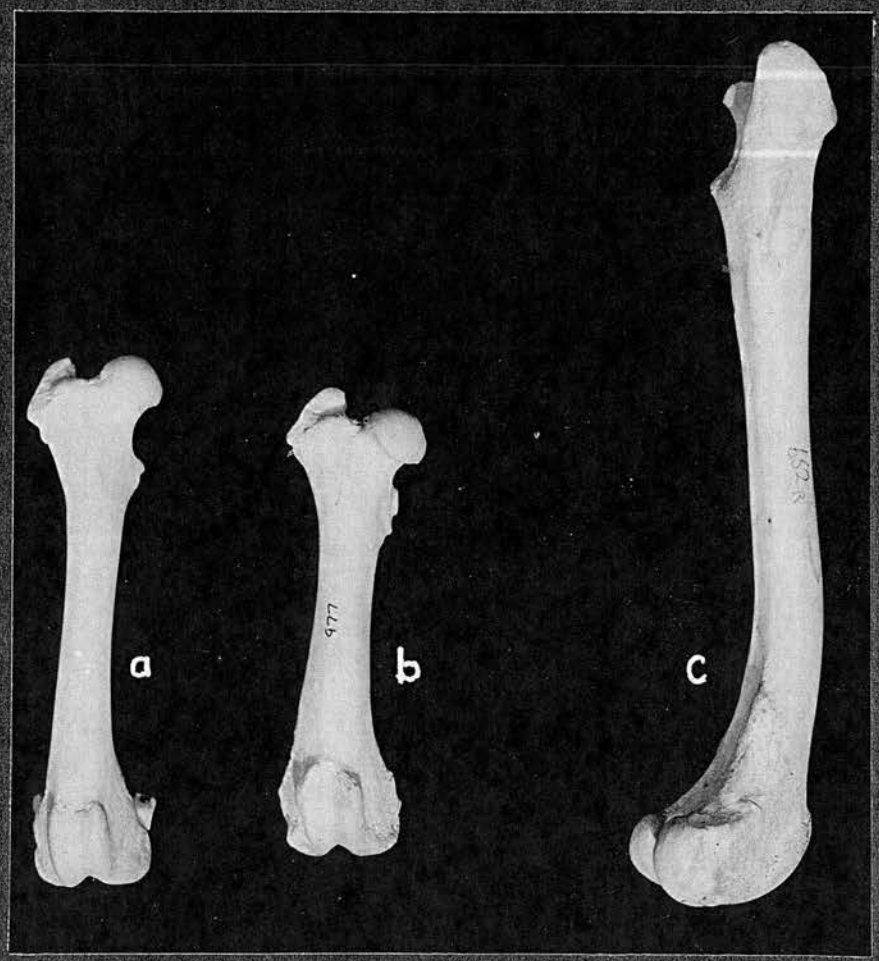


Fig.33

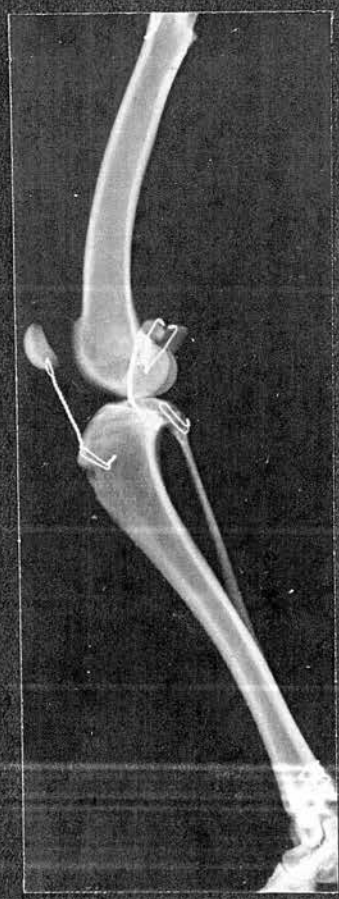


Fig.34

Figure 35. Lateral view of the pelvic limbs of a 25-day-old female collie.

(a) centre of ossification for the proximal epiphysis of the tibia.
(b) centre of ossification for the distal epiphysis of the tibia.
(c) centre of ossification for the central tarsal bone.
(d) centre of ossification for the third tarsal bone.
(e) centre of ossification for the fourth tarsal bone.

Figure 36. Plantarodorsal view of the tarsus of a 94-day-old male bulldog.

(a) centre of ossification for the medial malleolus of the tibia. Compare this with figure 19c.
(b) tibial tarsal bone.
(c) central tarsal bone.
(d) second tarsal bone.
(e) first tarsal bone.
(f) first metatarsal bone.
(g) fibular tarsal bone.
(h) fourth tarsal bone.
(i) third tarsal bone.

Fig. 35

Fig. 36

Figure 37. (a) Lateral view of the right tibia of skeleton (977) aged eleven and one-half months. It shows the proximal and distal epiphyses completely united with the diaphysis.

(b) Medial view of the right tibia of skeleton (652) aged ten and one-half months. It shows stage "3" union of the proximal epiphysis and complete union of the distal epiphysis with the diaphysis.

(c) Medial view of the right pelvic limb of skeleton (1359) aged ten months. It shows stage "3" union of the proximal epiphysis of the tibia and complete union of the distal epiphysis of the tibia with the diaphysis. Compare this figure with figure 34.

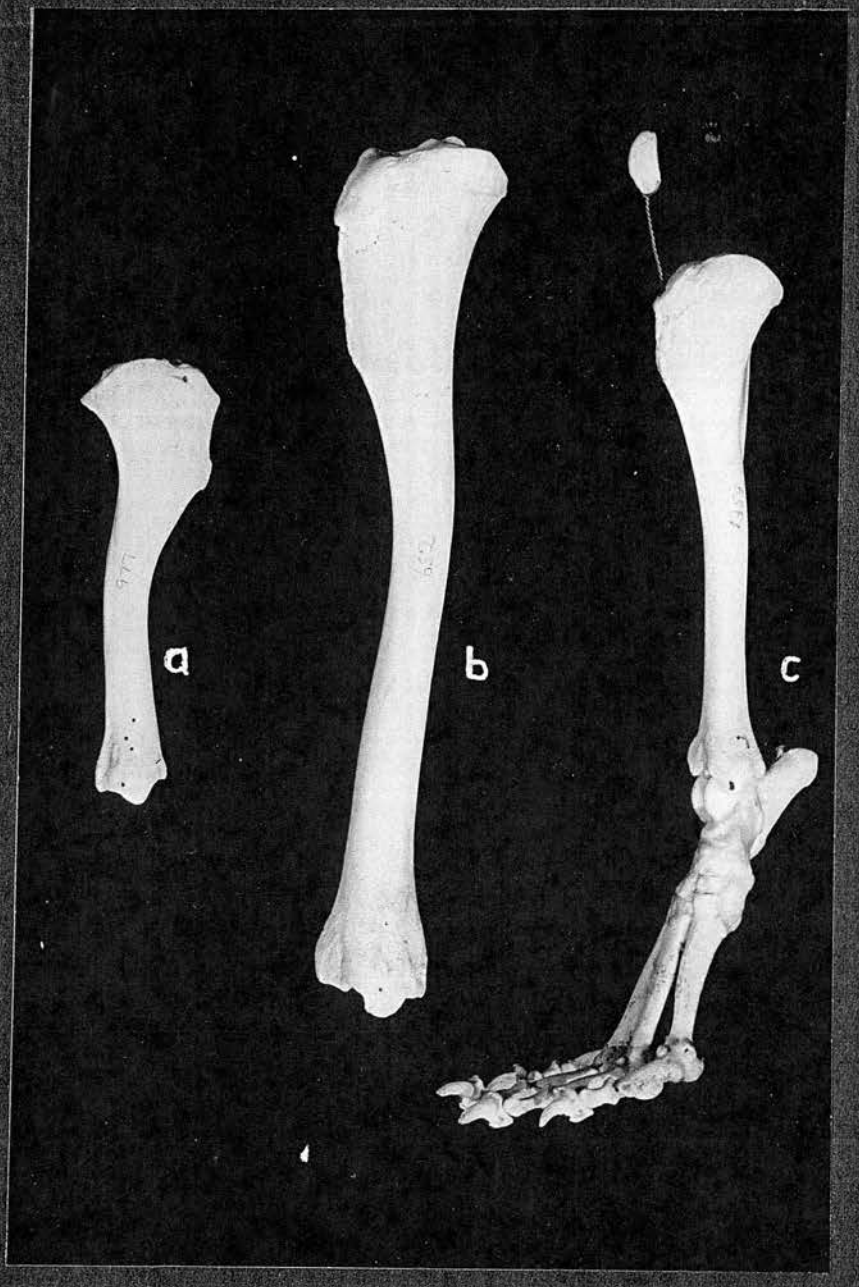


Fig.37

Figure 38. Mediolateral view of the right stifle of an 111-day-old female collie.

(a) centre of ossification for the tibial tuberosity, well developed.
(b) sesamoid bone in the tendon of the m. popliteus.
(c) centre of ossification for the proximal epiphysis of the fibula, well developed.

Figure 39. Plantarodorsal view of the distal end of the right tibia and fibula and of the foot of a 52-day-old male bulldog.

(a) centre of ossification for the distal epiphysis of the fibula.
(b) centre of ossification for the fourth tarsal bone.
(c) centre of ossification for the third tarsal bone.
(d) centres of ossification for the epiphyses of the metatarsal bones.
(e) centre of ossification for the central tarsal bone.
(f) centre of ossification for the second tarsal bone, just appearing.
(g) centre of ossification for the first tarsal bone.
(h) centres of ossification for the epiphyses of the proximal phalanges.

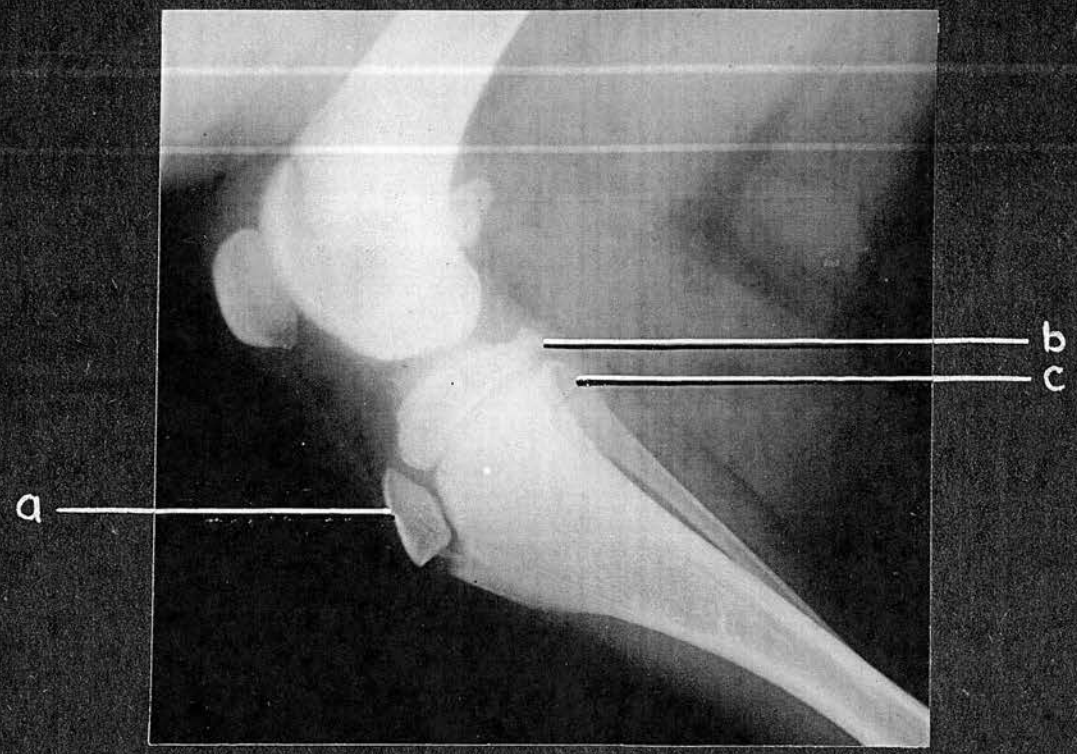


Fig.38

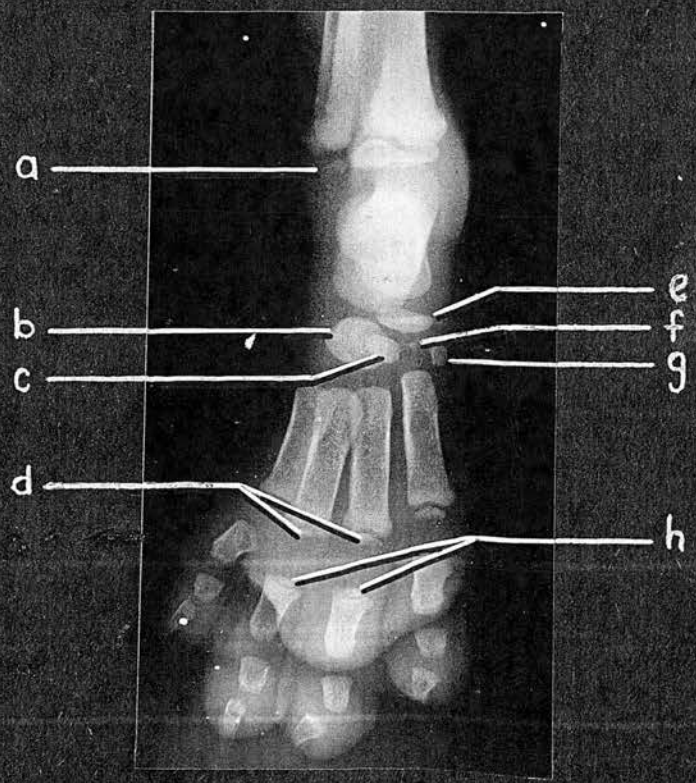


Fig.39

Figure 40. (a) Lateral view of the right fibula of skeleton (652) aged ten and one-half months. It shows complete union of the distal epiphysis and stage "3" union of the proximal epiphysis with the diaphysis. Note the break in the surface of the bone, indicated by the arrow, between the proximal epiphysis and the diaphysis. Compare this figure with figure 41.

(b) Lateral view of the left fibula of skeleton (977) aged eleven and one-half months. It shows the proximal and distal epiphyses completely united with the diaphysis.

Figure 41. Mediolateral view of the left femur and the proximal end of the tibia and fibula of skeleton (652) aged ten and one-half months. Compare this figure with figures 33c, 37b, and 40a.

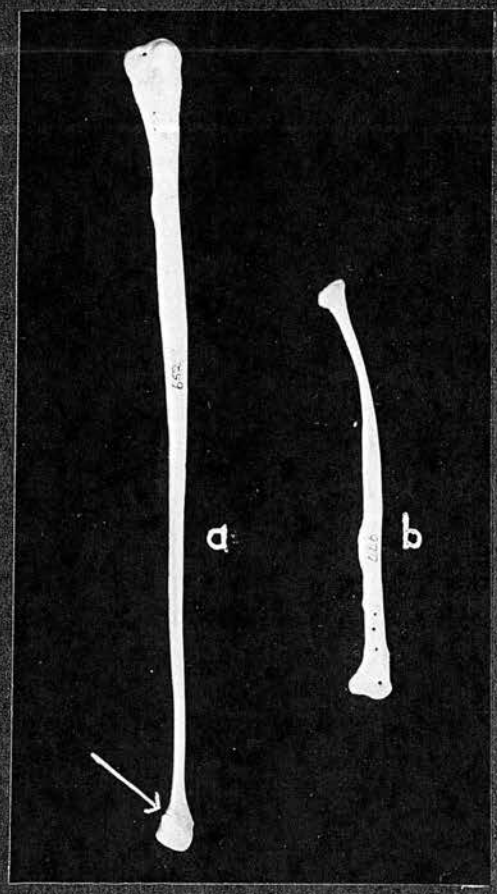


Fig. 40

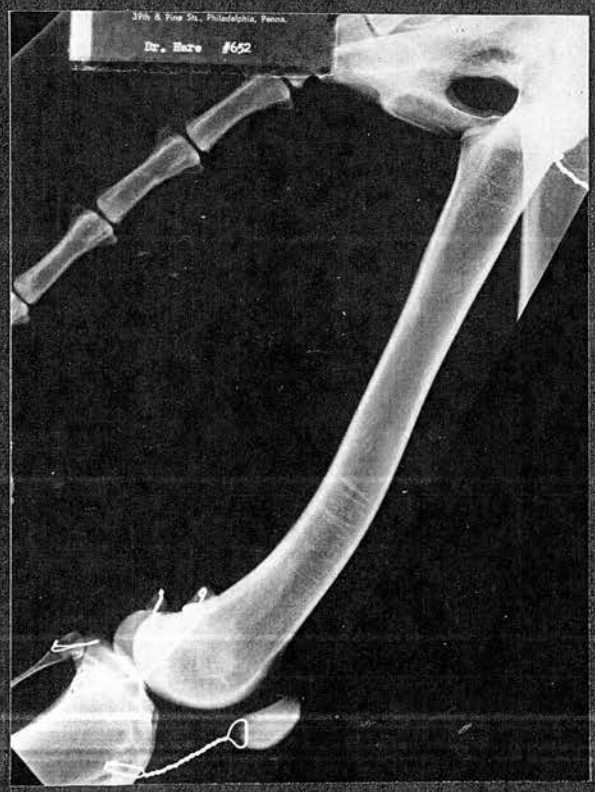


Fig. 41

Figure 42. Mediolateral view of the tarsus of a 46-day-old female German shepherd.

(a) two centres of ossification for the epiphysis of the fibular tarsal bone.
(b) centre of ossification for the first metatarsal bone, just appearing.

Figure 43. Mediolateral view of the tarsus of a 214-day-old female collie. It shows the epiphysis of the fibular tarsal bone completely united with the body.

Fig. 42

Fig. 43

Figure 44. Mediolateral view of the right forepaw of a 28-day-old female collie.

(a) centre of ossification for the intermediate carpal bone.
(b) centre of ossification for the third carpal bone.
(c) centre of ossification for the first carpal bone.
(d) centre of ossification for the accessory carpal bone.
(e) centre of ossification for the ulnar carpal bone.
(f) centre of ossification for the fourth carpal bone.
(g) centres of ossification for the epiphyses of the metacarpal bones.
(h) centres of ossification for the epiphyses of the proximal phalanges.

Figure 45. Mediolateral view of the right hindpaw of a 28-day-old female collie. Note that the epiphyses of the metatarsal bones and the proximal phalanges have not yet appeared as they have in the forepaw (figure 44).

(a) centre of ossification for the central tarsal bone.
(b) centre of ossification for the third tarsal bone.
(c) centre of ossification for the fourth tarsal bone.

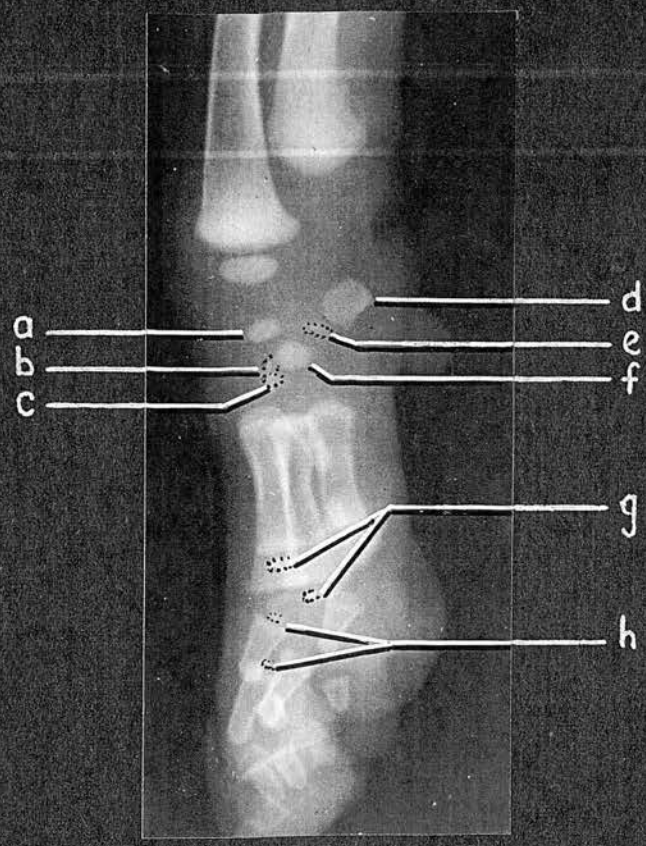


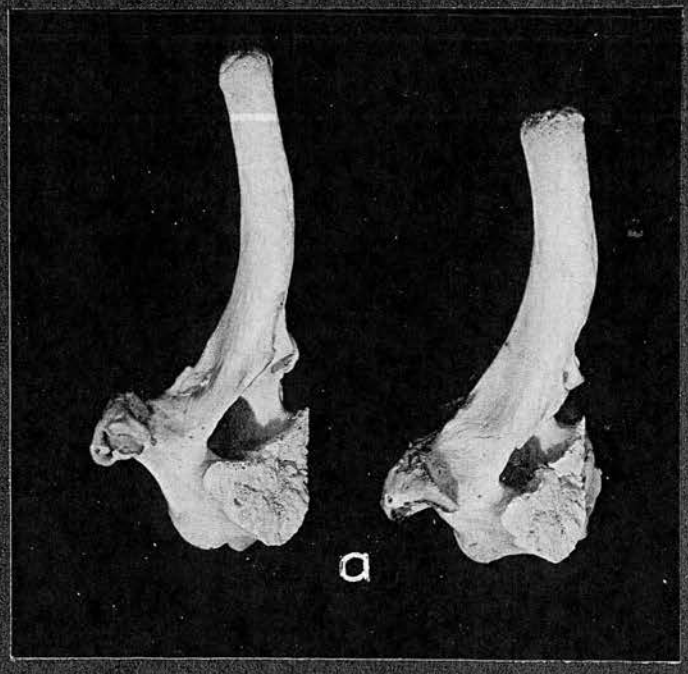
Fig. 44

Fig. 45

Figure 46. (a) Caudolateral view of the fourth and fifth thoracic vertebrae of skeleton (652) aged ten and one-half months.

(b) Craniolateral view of the fourth and fifth thoracic vertebrae of skeleton (652).

In this skeleton, the cranial and caudal epiphyses were completely united with the vertebrae except for the caudal epiphyses of the second to seventh thoracic vertebrae. The illustrations show that although the cranial epiphyses are completely united, the caudal epiphyses are not united with the bodies.



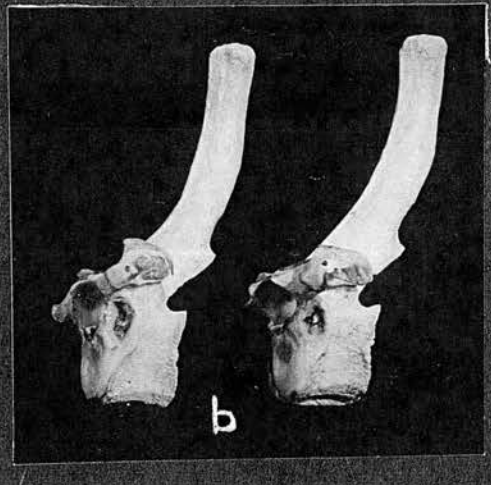


Fig. 46

Figure 47. Photograph of five skulls which illustrate the amount of wear on the incisor teeth at different ages.

(a) Skull (1336). This shows the trituberculate form of the crowns of the incisor teeth before wear has taken place.

(b) Skull (1644) aged eleven months. This shows wear on the lower first and second incisors.

(c) Skull (1683) aged twelve and one-half months. This shows the cusps worn off the lower first incisors and some wear on the lower second incisors.

(d) Skull (1011) aged twelve and one-half months. This shows the cusps worn off the lower first incisors.

(e) Skull (1491) aged thirteen and one-half months. This shows the cusps worn off the lower first incisors and some wear on the lower second incisors.

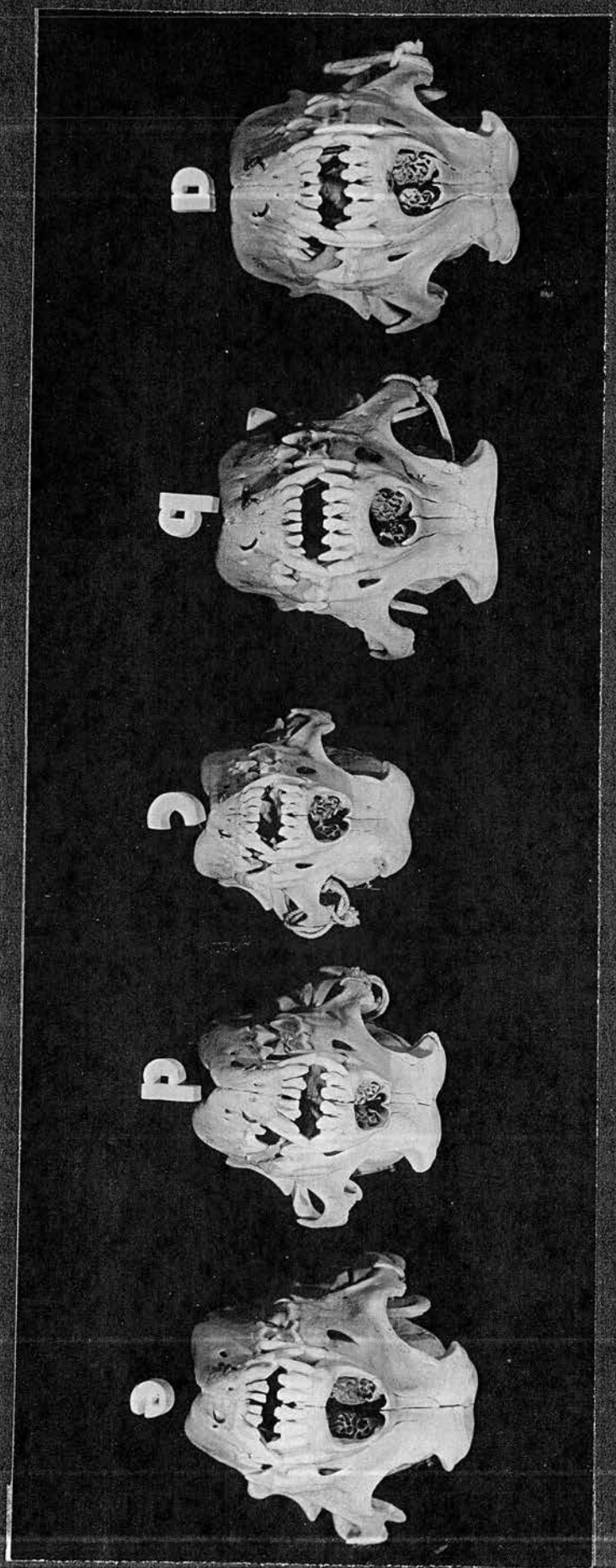
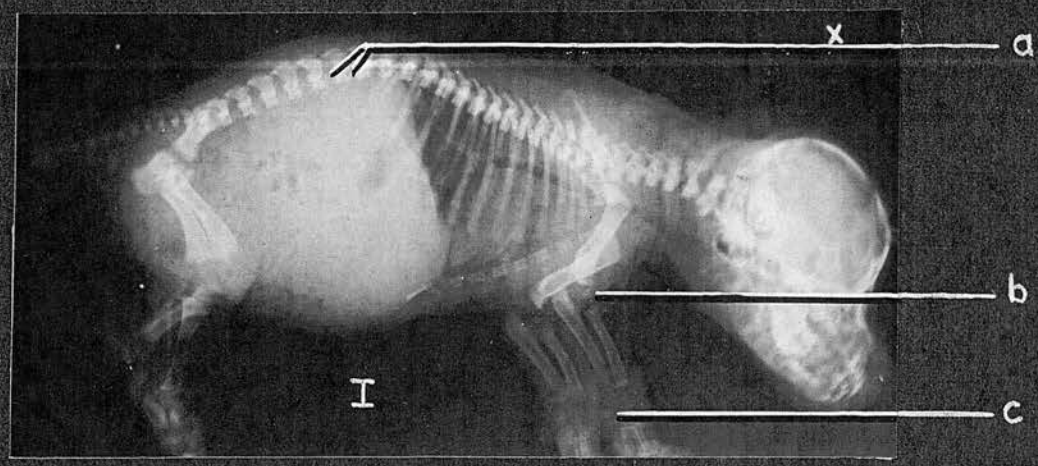


Fig.47

Figure 48. Lateral views of two 21-day-old beagles.. The female dog (I) was healthy, but the male dog (II) had helminthiasis. Note that dog (I) is larger than dog (II) and that its ossification process is more advanced in the vertebral column, elbow, and carpus.

(a) centres of ossification for the epiphyses of the bodies of the vertebrae.
(b) centre of ossification for the medial and lateral parts of the trochlea of the humerus.
(c) centre of ossification for the body of the accessory carpal bone.



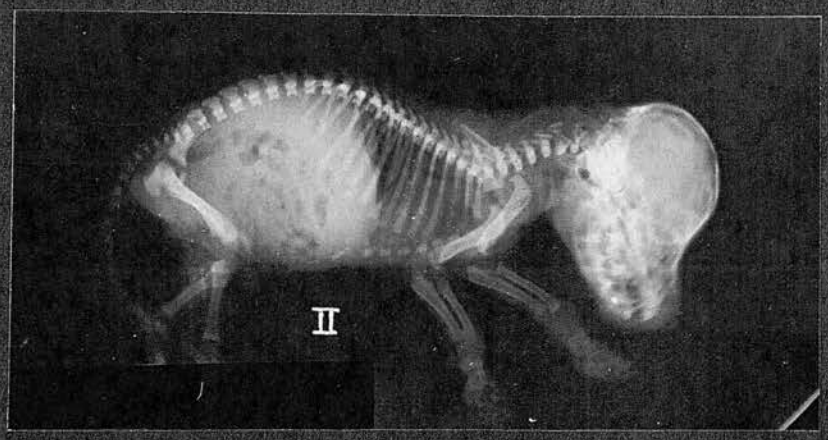


Fig. 48

Figure 49. Photograph of an illustration by Cornevin and Lesbre (1894). It shows the criteria which they established for ageing dogs by their teeth.

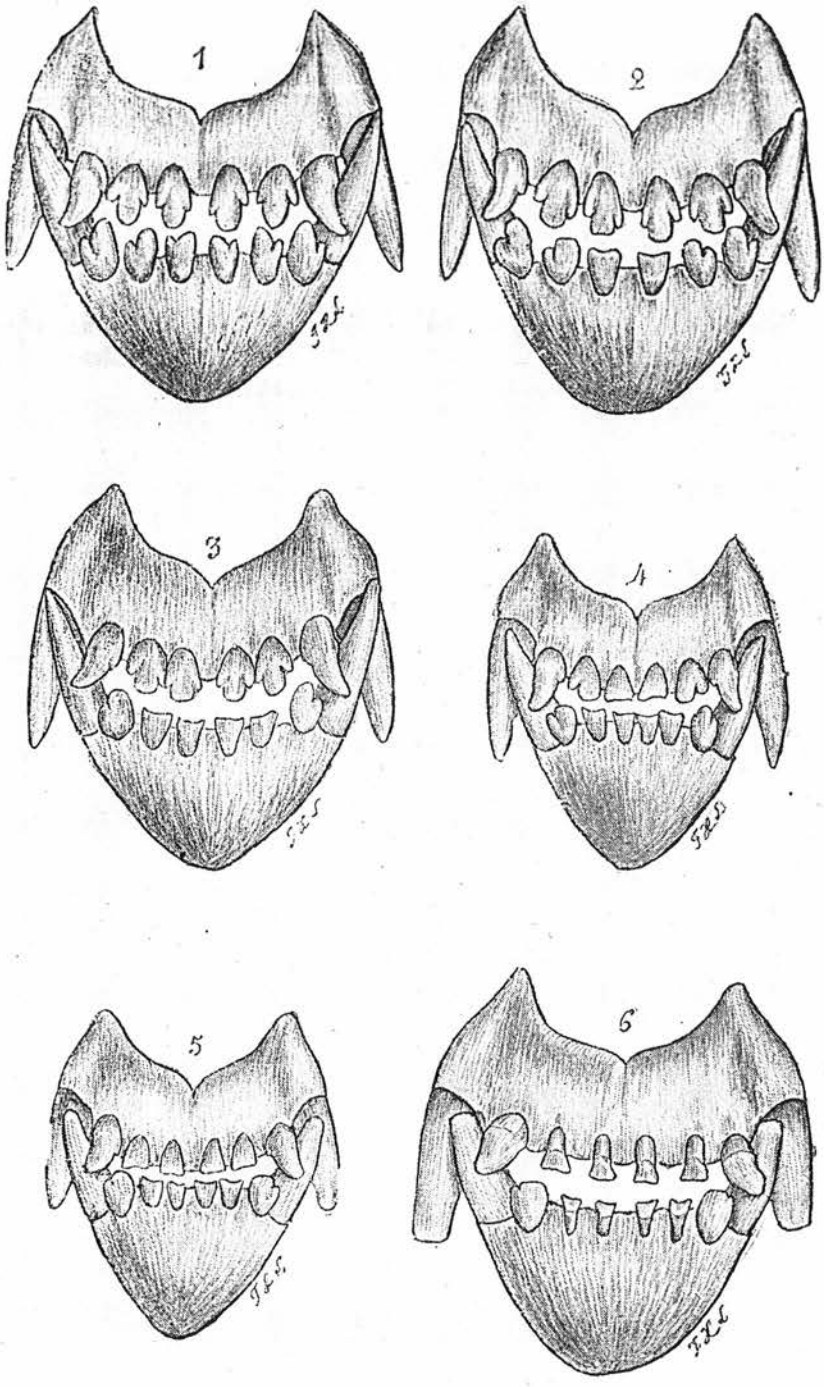


Fig. 203. — Bouts des mâchoires de chiens adultes.

1, un an. Les dents sont intactes.

2, 18 mois. Pinces inférieures nivelées.

3, 2 ans 1/2. Mitoyennes inférieures nivelées.

4, 4 ans. Pinces supérieures largement nivelées.

5, 5 ans. Mitoyennes supérieures nivelées.

6, 9 à 10 ans. Les coins supérieurs et les crochets sont très émoussés. Les incisives du centre sont usées jusqu'au voisinage du collet.

Fig. 49

Figure 50. Photograph of illustrations by Kroon (1929).

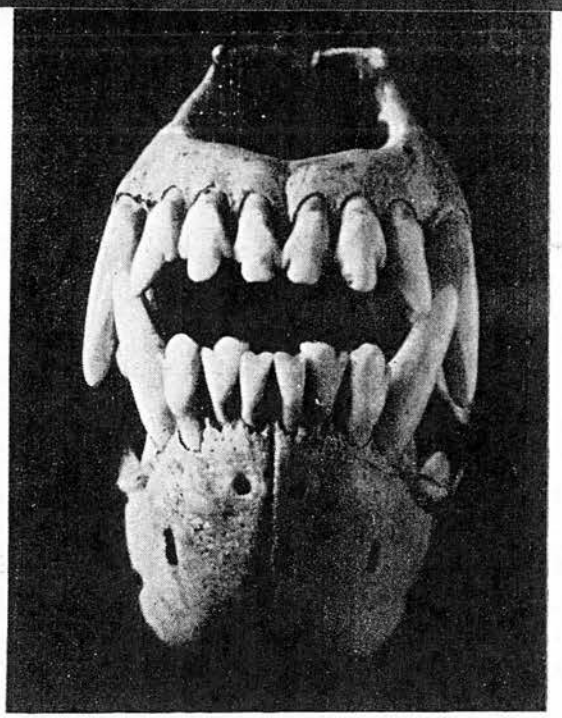


Fig. 101. Alter von 1 Jahr. Alle Ersatzschneidezähne vorhanden; im Oberkiefer noch deutlich dreilappig, im Unterkiefer zweilappig. An Zangen des Unterkiefers Spuren von Abnützung.

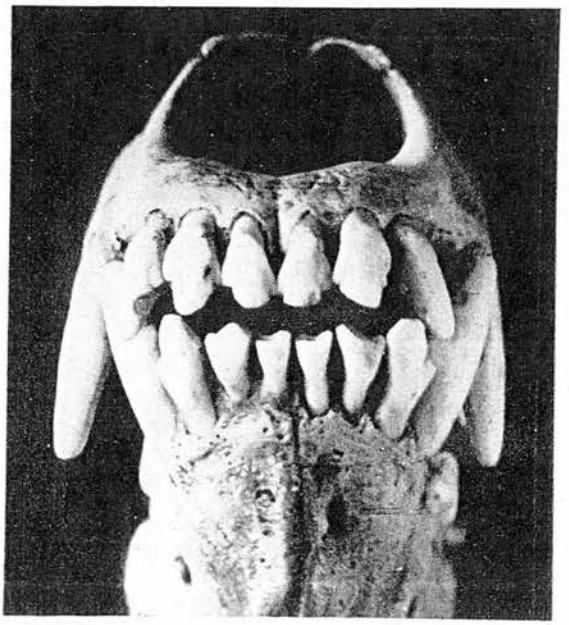
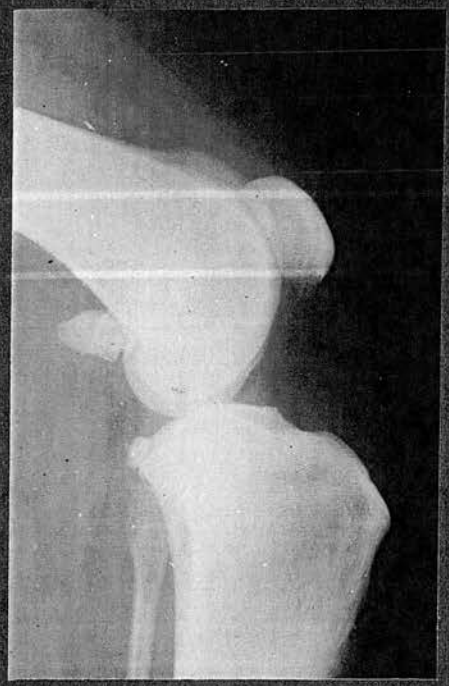


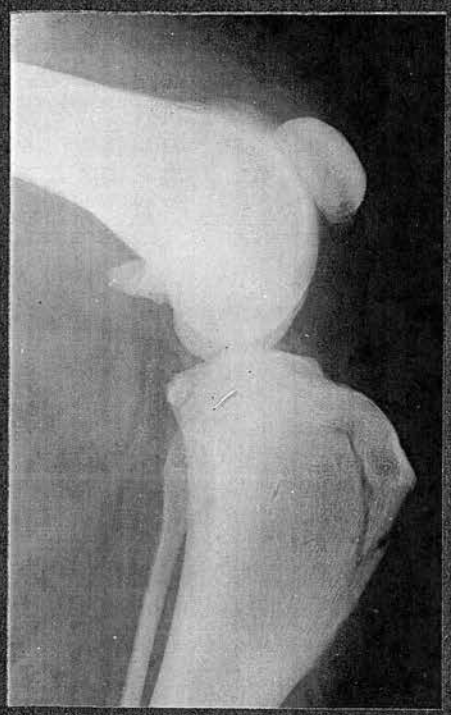
Fig. 102. Alter von gut 1½ Jahren. Hauptlappen an Zangen im Unterkiefer abgenützt; am linken Mittelzahn des Unterkiefers beginnt Abnützung.

Fig. 50

Figure 51. Mediolateral views of the stifle of three 277-day-old collies: (a) and (b) are of female dogs; and (c) is of a male dog.
Note that in dog (a) the proximal epiphyses of the tibia and fibula are completely united with their respective diaphyses, whereas in dogs (b) and (c) the proximal epiphyses of the tibia and fibula are not completely united with their respective diaphyses.



a



b

Fig. 51

c

APPENDIX "A"

The breeding records of the dogs used in the examination of the skeleton and teeth. $\frac{\text{Dam x Sire}}{\text{Dam x Sire}} = \frac{\text{Dam}}{\text{Sire}}$

Number	Sex	Breed	Parents
76	F.	Boston terrier	"Blossom"
82	F.	Foxhound	"Queeny"
83	F.	Bassethound	"Starridge Jill"
84	F.	Dachshund	"Astarte Kathe von Boris"
85	F.	Dachshund	"Jutta von Boris"
86	F.	St. Bernard	"Babe"
88	F.	Pekingese / Mattese terrier	——— / ———
93	M.	Foxhound	———
106	F.	Boston terrier	———
109	F.	Fr. Bulldog	"Sister"
110	F.	Chow Chow	537906
111	F.	G. Shepherd	"Thea"
114	F.	Fr. Bulldog	"Haworth Julie II"
118	F.	G. Shepherd	"Else"
120	M.	Bulldog	———
121	F.	Fr. Bulldog	"Spotty"
122	F.	Fr. Bulldog	"Frenchy"
123	M.	G. Shepherd / Basset	111 / ———
125	F.	G. Shepherd / Basset	111 / ———
127	F.	Dachshund / Boston	85 / 511318
128	M.	Dachshund / Boston	85 / 511318
129	M.	Dachshund / Boston	85 / 511318

APPENDIX "A"

Number	Sex	Breed	Parents
130	F.	Dachshund / Boston	85 / 511318
133	F.	Dachshund / Brussels Griffon	84 / 406514
134	M.	Dachshund / Brussels Griffon	84 / 406514
153	F.	Gt. Dane	"Allie"
155	F.	Gt. Dane	-------
156	F.	Gt. Dane	"Niger"
157	F.	Pomeranian	"Tippy"
158	F.	Cocker Spaniel	"Kisco Red Lady"
160	M.	Cocker Spaniel	-------
161	M.	Cocker Spaniel	"Jerry"
174	F.	Gt. Dane	156 / "Pandor H"
175	F.	Gt. Dane	156 / "Pandor H"
209	M.	Gt. Dane / St. Bernard	153 / "Palladium"
210	M.	G. Shepherd / Basset	111 / "Leader"
214	F.	Basset	83 / "Diligence"
215	M.	Basset	83 / "Diligence"
216	F.	Basset	83 / "Diligence"
227	F.	Foxhound / Basset	82 / "Drifter"
230	M.	Dachshund / Fr. Bulldog	85 / 122
231	M.	Dachshund / Fr. Bulldog	85 / 122

APPENDIX "A"

Number	Sex	Breed	Parents
234	F.	Fr. Bulldog / Dachshund	121 / -----
246	F.	G. Shepherd / Basset	118 / "Drifter"
247	F.	G. Shepherd / Basset	118 / "Drifter"
248	M.	G. Shepherd / Basset	118 / "Drifter"
251	M.	G. Shepherd / Basset	118 / "Drifter"
252	F.	Dachshund	-------
255	F.	Dachshund	85 / ------
264	M.	St. Bernard / Gt. Dane	86 / "Prinz"
265	F.	St. Bernard / Gt. Dane	86 / "Prinz"
266	F.	St. Bernard / Gt. Dane	86 / "Prinz"
274	M.	Gt. Dane / Bloodhound	155 / "Brutus"
275	F.	Gt. Dane / Bloodhound	155 / "Brutus"
277	F.	Basset	"Paula"
286	M.	Gt. Dane / St. Bernard	117 / ---
290	F.	Gt. Dane / St. Bernard	117 / ---
294	F.	Dachshund x Boston / Dachshund x Boston	127 / 129
295	F.	Dachshund x Boston / Dachshund x Boston	127 / 129
296	F.	Dachshund x Boston / Dachshund x Boston	127 / 129
303	M.	Labrador	"Captain"

APPENDIX "A"

Number	Sex	Breed	Parents
308	M.	Basset / G. Shepherd	277 / "Sheik"
310	F.	Basset / G. Shepherd	277 / "Sheik"
318	M.	Cocker Spaniel	158 / 161
319	F.	Cocker Spaniel	158 / 161
323	M.	Saluki	"Ptolmey"
345	M.	Dachshund x Boston / Dachshund x Boston	127 / 128
348	F.	Dachshund / Dachshund x Boston	255 / 128
352	M.	Dachshund x Boston / Dachshund x Boston	130 / 129
365	F.	Chow / Labrador	110 / 303
369	M.	Chow / Labrador	110 / 303
374	F.	G. Shepherd x Basset / G. Shepherd x Basset	247 / 248
381	M.	Foxhound x Basset / G. Shepherd x Bassett	227 / 210
391	F.	St. Bernard / Gt. Dane	86 / "Franz"
391	M.	St. Bernard / Gt. Dane	86 / "Franz"
398	F.	St. Bernard / Gt. Dane	86 / "FRanz"
402	F.	G. Shepherd x Basset / G. Shepherd x Basset	246 / 251
403	M.	G. Shepherd x Basset / G. Shepherd x Basset	246 / 251
404	M.	G. Shepherd x Basset / G. Shepherd x Basset	246 / 251
425	F.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230 & 231

APPENDIX "A"

Number	Sex	Breed	Parents
427	M.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230 & 231
433	F.	Boston Terrier	567179
435	F.	Boston Terrier	671167
437	F.	G. Shepherd	"Lady"
438	F.	G. Shepherd	437 / "Flanders"
481	M.	Cocker Spaniel / Saluki	158 / 323
486	M.	St. Bernard x Gt. Dane / St. Bernard x Gt. Dane	266 / 264
504	M.	Basset / Saluki	277 / 323
506	M.	Basset / Saluki	277 / 323
507	F.	Basset / Saluki	277 / 323
508	F.	Basset / Saluki	277 / 323
518	M.	Pomeranian / Saluki	157 / 323
524	M.	Boston / Dachshund x Boston	435 / 128
525	F.	Boston / Dachshund x Boston	435 / 128
532	M.	Dachshund x Fr. Bulldog / Dachshund x Fr. Bulldog	234 / 230
543	F.	Fr. Bulldog / Cocker Spaniel	109 / 161
553	M.	Boston / Dachshund	433 / ---
554	F.	Boston / Dachshund	433 / ---
555	F.	Boston / Dachshund	433 / ---

APPENDIX "A"

Number	Sex	Breed	Parents
558	M.	G. Shepherd x Basset / G. Shepherd x Basset	249 / 251
601	M.	Basset / Bulldog	277 / 651313
602	F.	Basset / Bulldog	277 / 651313
603	F.	Basset / Bulldog	277 / 651313
606	F.	Basset / Bulldog	277 / 651313
608	F.	Basset / Bulldog	216 / "Bosco"
620	M.	Dachshund x Boston / Dachshund x Boston	127 / 128
652	M.	G. Shepherd x Basset / G. Shepherd	247 / "Flanders"
653	F.	G. Shepherd x Basset / G. Shepherd	247 / "Flanders"
657	M.	G. Shepherd / Bulldog	118 / 651313
659	F.	G. Shepherd / Bulldog	118 / 651313
666	M.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230
667	F.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230
668	F.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230
669	F.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230
681	M.	Cocker Spaniel / Cocker Spaniel	319 / 318
684	F.	Cocker Spaniel / Cocker Spaniel	319 / 318
694	M.	Basset / Bulldog	216 / 651313

APPENDIX "A"

Number	Sex	Breed	Parents
695	M.	Basset / Bulldog	216 / 651313
739	M.	Basset / Bulldog	277 / 651313
741	M.	Basset / Bulldog	277 / 651313
743	F.	Basset / Bulldog	--- / ---
744	F.	Basset / Bulldog	--- / ---
765	F.	Bloodhound	---
772	M.	Boston / Dachshund x Boston	"Flash" / 129
773	M.	Boston / Dachshund x Boston	"Flash" / 129
778	M.	Boston x Dachshund / Boston x Dachshund	554 / 553
779	M.	Boston x Dachshund / Boston x Dachshund	554 / 553
781	F.	Boston x Dachshund / Boston x Dachshund	554 / 553
782	M.	Boston x Dachshund / Boston x Dachshund	554 / 553
783	M.	Fr. Bulldog x Cocker Sp. / Cocker Spaniel	543 / 161
784	F.	Fr. Bulldog x Cocker Sp. / Cocker Spaniel	543 / 161
810	M.	Dachshund x Boston / Dachshund x Boston	127 / 128
811	F.	Dachshund x Boston / Dachshund x Boston	127 / 128
827	F.	Gt. Dane / Gt. Dane x Bloodhound	175 / 274
833	F.	Saluki	"Sheba"
853	F.	St. Bernard x Gt. Dane / St. Bernard x Gt. Dane	391 / 392

APPENDIX "A"

Number	Sex	Breed	Parents
858	M.	Basset / Basset x Saluki	216 / 506
860	F.	Basset / Basset x Saluki	216 / 506
876	M.	Basset x Bulldog / Bulldog	603 / 651313
903	M.	Bulldog	651313
916	F.	Basset x Bulldog / Basset x Bulldog	608 / 601
917	F.	Basset x Bulldog / Basset x Bulldog	608 / 601
918	F.	Basset x Bulldog / Basset x Bulldog	608 / 601
919	F.	Basset x Bulldog / Basset x Bulldog	608 / 601
932	M.	Basset x Saluki / Basset x Saluki	507 / 504
933	F.	Basset x Saluki / Basset x Saluki	507 / 504
957	F.	G. Shepherd x Bulldog / Bulldog	659 / Drew's "Big No"
959	F.	G. Shepherd x Bulldog / Bulldog	659 / Drew's "Big No"
977	M.	Basset x Bulldog / Basset x Bulldog	602 / 601
995	F.	Basset x Bulldog / Basset x Bulldog	743 / 741
1010	F.	Basset / Basset x Bulldog	277 / 601
1011	F.	Basset / Basset x Bulldog	277 / 601
1012	M.	SAluki / Basset x Saluki	833 / 506
1016	F.	Saluki / Basset x Saluki	833 / 506

APPENDIX "A"

Number	Sex	Breed	Parents
1028	M.	Basset x Saluki / Basset x Saluki	508 / 504
1032	F.	Basset x Saluki / Basset x Saluki	508 / 504
1033	F.	Basset x Saluki / Basset x Saluki	508 / 504
1034	F.	Basset x Saluki / Basset x Saluki	508 / 504
1055	F.	Basset x Bulldog / Basset x Bulldog	744 / 741
1062	F.	St. Bernard x Gt. Dane / St. Bernard x Gt. Dane	398 / 486
1072	M.	G. Shepherd	---
1083	F.	Bulldog	---
1087	F.	Dachshund x Boston / Dachshund x Boston	781 / 782
1088	F.	Dachshund x Boston / Dachshund x Boston	781 / 782
1089	F.	Dachshund x Boston / Dachshund x Boston	781 / 782
1094	M.	Chow x Labrador / Chow x Labrador	365 / 369
1097	F.	Chow x Labrador / Chow x Labrador	365 / 369
1100	M.	Dachshund x Fr. Bulldog / Dachshund x Fr. Bulldog	425 / 230
1103	F.	Dachshund x Fr. Bulldog / Dachshund x Fr. Bulldog	425 / 230
1106	F.	Boston x Dachshund / Dachshund x Boston	554 / 128
1107	F.	Boston x Dachshund / Dachshund x Boston	554 / 128
1111	M.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230
1112	M.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230

APPENDIX "A"

Number	Sex	Breed	Parents
1115	F.	Fr. Bulldog x Dachshund / Dachshund x Fr. Bulldog	234 / 230
1118	M.	Pekingese	---
1132	M.	G. Shepherd	"Belgium"
1141	M.	Bloodhound / Gt. Dane x St. Bernard	765 / 286
1144	M.	Basset x Bulldog / Basset x Bulldog	608 / 601
1146	M.	Basset x Bulldog / Basset x Bulldog	608 / 601
1147	M.	Basset x Bulldog / Basset x Bulldog	608 / 601
1152	M.	G. Shepherd x Basset / Basset x G. Shepherd	246 / 308
1155	M.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	398 / 286
1158	M.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	398 / 286
1159	M.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	398 / 286
1160	F.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	398 / 286
1165	F.	Cocker Spaniel / Dachshund	319 / "Rudy v. W."
1166	F.	Cocker Spaniel / Dachshund	319 / "Rudy v. W."
1176	F.	Dachshund	---
1211	M.	Basset x Saluki / Basset x Saluki	507 / 506
1213	M.	Basset x Saluki / Basset x Saluki	507 / 506
1214	F.	Basset x Saluki / Basset x Saluki	507 / 506
1215	F.	Basset x Saluki / Basset x Saluki	507 / 506

APPENDIX "A"

Number	Sex	Breed	Parents
1216	F.	Basset x Saluki / Basset x Saluki	507 / 506
1227	M.	G. Shepherd x Bulldog / G. Shepherd	659 / 1132
1228	M.	G. Shepherd x Bulldog / G. Shepherd	659 / 1132
1229	M.	G. Shepherd x Bulldog / G. Shepherd	659 / 1132
1230	M.	G. Shepherd x Bulldog / G. Shepherd	659 / 1132
1231	F.	G. Shepherd x Bulldog / G. Shepherd	659 / 1132
1235	F.	Dachshund x Fr. Bulldog / Dachshund x Fr. Bulldog	425 / 230
1237	F.	Dachshund x Fr. Bulldog / Dachshund x Fr. Bulldog	425 / 230
1242	M.	Boston x Dachshund / Boston x Dachshund	554 / 620
1247	M.	Basset x Bulldog / Basset x Bulldog	602 / 601
1248	M.	Basset x Bulldog / Basset x Bulldog	602 / 601
1249	M.	Basset x Bulldog / Basset x Bulldog	602 / 601
1251	F.	Basset x Bulldog / Basset x Bulldog	602 / 601
1263	M.	Basset / Dachshund	277 / "Rudy v. W."
1264	M.	Basset / Dachshund	277 / "Rudy v. W."
1265	F.	Basset / Dachshund	277 / "Rudy v. W."
1266	F.	Basset / Dachshund	277 / "Rudy v. W."
1267	M.	Dachshund x Dachshund-Boston / Codker-Spaniel	348 / 681

APPENDIX "A"

Number	Sex	Breed	Parents
1271	F.	Dachshund x Dachshund-Boston Cocker-Spaniel	348 / 681
1279	M.	Bloodhound Gt. Dane	765 "Ajax"
1281	F.	Bloodhound Gt. Dane	765 "Ajax"
1283	M.	G. Shepherd	438 / 1132
1284	M.	G. Shepherd	438 / 1132
1285	F.	G. Shepherd	438 / 1132
1311	M.	Basset x Bulldog Basset x Bulldog	608 / 694
1312	M.	Basset x Bulldog Basset x Bulldog	608 / 694
1313	M.	Basset x Bulldog Basset x Bulldog	608 / 694
1315	F.	Basset x Bulldog Basset x Bulldog	608 / 694
1317	F.	Basset x Bulldog Basset x Bulldog	608 / 694
1340	M.	Cocker-Spaniel Dachshund	"Red Lady II" "Rudy v. W."
1341	M.	Cocker-Spaniel Dachshund	"Red Lady II" "Rudy v. W."
1342	F.	Cocker-Spaniel Dachshund	"Red Lady II" "Rudy v. W."
1343	F.	Cocker-Spaniel Dachshund	"Red Lady II" "Rudy v. W."
1344	F.	Cocker-Spaniel Dachshund	"Red Lady II" "Rudy v. W."
1349	F.	Basset Dachshund	216 "Muck"
1359	M.	Basset x Bulldog Basset x Bulldog	743 / 601
1385	F.	Saluki x Basset-Saluki Saluki x Basset-Saluki	1016 / 1012

APPENDIX "A"

Number	Sex	Breed	Parents
1399	M.	Basset x Basset-Saluki / Basset x Basset-Saluki	860 / 858
1400	M.	Basset x Basset-Saluki / Basset x Basset-Saluki	860 / 858
1401	F.	Basset x Basset-Saluki / Basset x Basset-Saluki	860 / 858
1417	M.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	265 / 286
1418	F.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	265 / 286
1419	F.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	265 / 286
1421	F.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	265 / 286
1422	F.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	265 / 286
1434	F.	G. Shepherd x Basset / G. Shepherd x Basset	247 / 308
1440	M.	Basset x Saluki / Basset x Saluki	507 / 506
1441	M.	Basset x Saluki / Basset x Saluki	507 / 506
1442	M.	Basset x Saluki / Basset x Saluki	507 / 506
1443	M.	Basset x Saluki / Basset x Saluki	507 / 506
1444	M.	Basset x Saluki / Basset x Saluki	507 / 506
1445	F.	Basset x Saluki / Basset x Saluki	507 / 506
1447	M.	G. Shepherd x Bulldog / Bulldog	659 / "Sonny"
1448	M.	G. Shepherd x Bulldog / Bulldog	659 / "Sonny"
1449	M.	G. Shepherd x Bulldog / Bulldog	659 / "Sonny"
1452	F.	G. Shepherd x Bulldog / Bulldog	659 / "Sonny"

APPENDIX "A"

Number	Sex	Breed	Parents
1453	F.	G. Shepherd x Bulldog / Bulldog	659 / "Sonny"
1455	F.	G. Shepherd x Bulldog / Bulldog	659 / "Sonny"
1466	M.	Bulldog	"Duke"
1478	M.	Basset x Bulldog / Bulldog	608 / 1466
1479	M.	Basset x Bulldog / Bulldog	608 / 1466
1481	F.	Basset x Bulldog / Bulldog	608 / 1466
1482	F.	Basset x Bulldog / Bulldog	608 / 1466
1488	F.	Basset x Bulldog / Basset x Bulldog	602 / 601
1490	M.	Basset x G. Shepherd / Basset x G. Shepherd	310 / 308
1491	M.	Basset x G. Shepherd / Basset x G. Shepherd	310 / 308
1492	M.	Basset x G. Shepherd / Basset x G. Shepherd	310 / 308
1493	M.	Basset x G. Shepherd / Basset x G. Shepherd	310 / 308
1518	M.	Boston x Dachshund / Boston x Dachshund	555 / 553
1519	M.	Boston x Dachshund / Boston x Dachshund	555 / 553
1520	F.	Boston x Dachshund / Boston x Dachshund	555 / 553
1522	M.	Boston x Dachshund / Boston x Dachshund	554 / 553
1523	M.	Boston x Dachshund / Boston x Dachshund	554 / 553
1525	F.	Boston x Dachshund / Boston x Dachshund	554 / 553
1526	F.	Boston x Dachshund / Boston x Dachshund	554 / 553

APPENDIX "A"

Number	Sex	Breed	Parents
1536	F.	Gt. Dane x St. Bernard / Gt. Dane x St. Bernard	290 / 286
1582	F.	Basset x Bulldog / Basset x Bulldog	606 / 704
1626	M.	Basset x Dachshund / Basset x Dachshund	1266 / 1264
1632	M.	Basset x Dachshund / Basset x Dachshund	1265 / 1263
1633	M.	Basset x Dachshund / Basset x Dachshund	1265 / 1263
1635	F.	Basset x Dachshund / Basset x Dachshund	1265 / 1263
1636	F.	Basset x Dachshund / Basset x Dachshund	1265 / 1263
1644	M.	G. Shepherd / G. Shepherd	1285 / 1132
1653	M.	Basset x G. Shepherd / Basset x G. Shepherd	310 / 251
1683	M.	Cocker Spaniel x Dachshund / Cocker Spaniel x Dachshund	1344 / 1340
1686	M.	Basset x Dachshund / Basset x Dachshund	1349 / 1264
1695	M.	Boston x Dachshund / Boston x Dachshund	554 / 553
1696	M.	Boston x Dachshund / Boston x Dachshund	554 / 553
1698	F.	Boston x Dachshund / Boston x Dachshund	554 / 553
1699	F.	Boston x Dachshund / Boston x Dachshund	554 / 553
1700	F.	Boston x Dachshund / Boston x Dachshund	554 / 553
1739	M.	St. Bernard x Gt. Dane / Gt. Dane x St. Bernard	391 / 286
1746	M.	Cocker Spaniel x Dachshund / Cocker Spaniel x Dachshund	1342 / 1341
1747	M.	Cocker Spaniel x Dachshund / Cocker Spaniel x Dachshund	1342 / 1341

APPENDIX "A"

Number	Sex	Breed	Parents
1748	F.	Cocker Spaniel x Dachshund Cocker Spaniel x Dachshund	1342 1341
1769	F.	St. Bernard X Gt. Dane St. Bernard x Gt. Dane	1418 1417
1813	M.	Basset x G. Shepherd G. Shepherd x Basset	310 251
1830	M.	G. Shepherd x Bulldog Gt. Dane x Bloodhound	659 ---
1832	F.	G. Shepherd x Bulldog Gt. Dane x Bloodhound	659 ---
1834	F.	G. Shepherd x Bulldog Gt. Dane x Bloodhound	659 ---
1847	M.	Cocker Spaniel x Dachshund Cocker Spaniel x Dachshund	1165 1341
1859	M.	Boston x Dachshund Boston x Dachshund	555 553
1862	F.	Boston x Dachshund Boston x Dachshund	555 553
1876	M.	Bloodhound x Gt. Dane Gt. Dane x Bloodhound	1281 274
1877	M.	Bloodhound x Gt. Dane Gt. Dane x Bloodhound	1281 274
1890	F.	Dachshund Pekingese	1176 1118
1899	F.	Basset x Saluki Basset x Saluki	508 504
1901	M.	Basset x Dachshund Basset x Dachshund	1266 1264
1902	M.	Basset x Dachshund Basset x Dachshund	1266 1264
1903	M.	Basset x Dachshund Basset x Dachshund	1266 1264
1904	M.	Basset x Dachshund Basset x Dachshund	1266 1264
1905	F.	Basset x Dachshund Basset x Dachshund	1266 1264
1906	F.	Basset x Dachshund Basset x Dachshund	1266 1264

APPENDIX "A"

Number	Sex	Breed	Parents
1908	M.	Basset x Saluki Basset x Saluki	507 506
1910	M.	Basset x Saluki Basset x Saluki	507 506
1914	M.	Basset x Dachshund Basset x Dachshund	1265 1263
1915	M.	Basset x Dachshund Basset x Dachshund	1265 1263
1916	M.	Basset x Dachshund Basset x Dachshund	1265 1263
1917	M.	Basset x Dachshund Basset x Dachshund	1265 1263
1918	M.	Basset x Dachshund Basset x Dachshund	1265 1263
1924	F.	St. Bernard x Gt. Dane Gt. Dane x St. Bernard	391 286

APPENDIX "B"

The age distribution of the skeletons, pectoral limbs, and skulls that were used in this study.

Age	Skeletons and pectoral limbs	Skulls
2 1/2 - 3 m	1748	
3 - 3 1/2 m		957, 959, 1088, 1089, 1908, 1832, 1862, 1859, 1910
3 1/2 - 4 m	174, 481	174, 481, 1087, 1166, 1279, 1315, 1813, 1830, 1834, 1899
4 - 4 1/2 m	381, 427	381, 427, 1106, 1876, 1877
4 1/2 - 5 m	275	275, 1249, 1253, 1283, 1284, 1916
5 - 5 1/2 m	88, 345, 1890	345, 1235, 1242, 1247, 1248, 1434, 1653, 1890
5 1/2 - 6 m		
6 - 6 1/2 m	133, 215	133, 215, 784, 2333
6 1/2 - 7 m		783
7 - 7 1/2 m	125	125, 1141
7 1/2 - 8 m	404	404
8 - 8 1/2 m	123, 160, 214, 657	123, 160, 1100
8 1/2 - 9 m		
9 - 9 1/2 m	1847	778, 1097, 1847
9 1/2 - 10 m		1230
10 - 10 1/2 m	695, 811, 1359, 1518, 1520, 1699, 1700	695, 810, 811, 1111, 1112, 1227, 1700
10 1/2 - 11 m	652, 1519, 1746	1032, 1228, 1400, 1746
11 - 11 1/2 m		1028, 1115, 1399, 1644
11 1/2 - 12 m	653, 977, 1686, 1698	653, 1155, 1698

APPENDIX "B"

Age	Skeletons and pectoral limbs	Skulls
12 - 12 1/2 m	1632, 1633, 1635, 1636	772, 773, 1010, 1033, 1034, 1237
12 1/2 - 13 m	1683, 1695, 1696	1011, 1231, 1683
13 - 13 1/2 m	1747, 1924	933, 1107, 1229, 1747, 1769, 1924
13 1/2 - 14 m	76	1317, 1490, 1491, 1492, 1493
14 - 14 1/2 m	93, 916, 917, 918, 919, 1522, 1523, 1526	93, 1158, 1159, 1160, 1523, 1526, 1536
14 1/2 - 15 m	518, 1525	518, 1525
15 - 15 1/2 m	402, 403, 667, 668, 669, 1146, 1251	374, 402, 403, 666, 667, 995, 1267, 1271
15 1/2 - 16 m		1055
16 - 16 1/2 m	1447, 1448, 1449, 1452, 1453, 1455, 1488	932
16 1/2 - 17 m	1211, 1216, 1914, 1915, 1917, 1918	853, 1147, 1211, 1417, 1917
17 - 17 1/2 m	666, 1901, 1902, 1903, 1904, 1905, 1906	1902, 1903, 1904, 1905, 1906
17 1/2 - 18 m	782, 1481, 1482	1103
18 - 19 m	876	827, 1062, 1419, 1421, 1422
19 - 20 m	106, 352, 779, 1478, 1479	
20 - 21 m	524, 525, 1311, 1312, 1313, 1385	
21 - 22 m	532, 1440, 1441, 1444	
22 - 23 m	1263	
23 - 24 m	1144, 1442, 1443	
24 - 30 m	294, 684, 1072, 1213, 1215, 1445, 1626	
30 - 36 m	84, 209, 210, 231, 1214, 1401	

APPENDIX "B"

Age	Skeletons and pectoral limbs	Skulls
36 - 42 m	114, 295, 296, 486, 739, 1083, 1094, 1343	
42 - 48 m	109, 130, 134, 1582	
48 - 54 m	318, 833, 1152	
54 - 60 m	85, 128, 156, 252	
60 - 72 m	120, 122, 127, 230, 234	
over 72 m	277, 391, 504	